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Effect of fungal degradation on physicochemical properties of exploited stumps of oriental beech over a 25-year felling period and the obtained Kraft pulp properties

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Abstract: Oriental beech (*Fagus orientalis* Lipsky) is the most important and valuable industrial wood species in the Hyrcanian forests in the north of Iran mainly used for furniture, veneer, composite, and papermaking industries. The present research was conducted in 2014 aimed at investigating the physicochemical changes of the felled oriental beech stumps over a 2–25 year period, and likewise the feasibility of using the given stumps as an alternative resource for wood pulp production. To do so, the effects of *in-situ* decay of beech stumps on their physical (wet and dry weights of wood, wet apparent density, and dry apparent density) and chemical (cellulose, hemicellulose, lignin, extractives, and total mass of carbohydrates) properties over a 2–25 year felling period were studied. The effects of the given decay period were also studied on the obtained Kraft pulp yield and Kappa number. The results indicate that the wet and dry apparent densities as well as the wet and dry weights of the wood samples decreased over the study period. Also, the results show that approximately 30% of the total mass of carbohydrates was degraded by the ambient fungi over the initial two years of felling, whereas the same property was reduced by 60% after 25 years. The Kraft pulp yields obtained from 2- and 25-year decayed stumps were 22.5% and 8.4%, respectively. The fungal degradation of wood chemical compounds could considerably reduce pulp yield and Kappa number by 62.8% and 74.2%, respectively. The results of a stepwise multivariate regression model evidence that cellulose not only affects the Kappa number but also owns a greater share (*vs.* lignin) in modelling the Kappa number. This reveals that the intensity of cellulose degradation, due to fungal exposure, is significantly higher than that of the other components of beech stumps in the studied forest area.

Keywords: Beech wood; decayed stumps; wood density; weight; chemical compounds; white rot fungi

Hyrcanian forests located between the northern slopes of the Alborz mountain range and the southern margin of the Caspian Sea are the only commercial forests of Iran which cover an area of about 1.9 million hectares (Shayanmehr et al. 2015; Colagar et al. 2016; Nourmohammadi et al. 2016). *Fagus orientalis* Lipsky is undoubtedly considered as the most important and invaluable industrial wood species of Hyrcanian forests of Iran growing at altitudes of 450 to 2,200 m a. s. l. It is also the Iranian variety of its European counterpart, i.e. *Fagus sylvatica* (Kartoolinejad et al. 2017).

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Due to its shade-demanding trait, proper regeneration, competitiveness, and longevity, the given species grows as a dominant species in most forest stands (Azadfar et al. 2004).

Besides economic advantages, the beech tree holds a suitable potential to be used in wood product industries such as furniture, decoration, cabinet making, etc., as well as papermaking products, e.g. wood pulp, paper tissue, sanitary cellulosic products, etc. (Akgul, Tozluglu 2009).

Environmental concerns, in particular shortage of wood resources, entail the use of alternative resources for massive wood such as wood wastes as well as agricultural residues after harvest (e.g. wheat straw, rice hulls, and sugarcane residue or bagasse). The decayed felled stumps existing in natural forests are another potential resource for the production of various wood products, in particular pulp and paper. The penetration of fungal mycelia into the exploited stumps results in the degradation of wood polymers (cellulose, hemicelluloses, and lignin). This increases wood porosity (*vs.* density) and brings about easier penetration of pulping liquor in wood chips leading to reduced cooking time as well as consumption of cooking chemicals. Therefore, not only the amount of energy required for cooking would be reduced but also contaminant gases produced by the Kraft pulping process (e.g. hydrogen sulphide, methyl mercaptan, dimethyl sulphide, and dimethyl disulphide) would be drastically diminished (Fonseca et al. 2014; Silva et al. 2016).

The properties of wood pulp are considerably affected by the physical and chemical properties of massive wood and its constituent polymers, e.g. cellulose, hemicelluloses, lignin, and extractives (Liu et al. 2008; Marvi-Mohadjer 2013). Wood-decaying fungi are amongst the deteriorating factors which can attack and/or decay both living and dead trees. They degrade the chemical compounds of decaying wood and thus result in the gradual reduction of weight, the indicator by which the amount of decay is assessed and measured (Nadali et al. 2010), and thus density of the attacked wood biomass (Bari et al. 2015; Nadali et al. 2018).

Wood-decaying white and brown rot fungi can mainly degrade lignin and cellulose, respectively, leading to reduced quality of the obtained pulp and paper; that is, they attack the carbohydrate compounds of wood and thus separate the end-chain glycosidic units through a mechanism called peeling (Li et al. 2007; Nevalainen et al. 2017; Tavares et al. 2017); however the above-mentioned authors did not study the effect of fungal degradation on the obtained pulp properties.

Bari et al. (2015) studied the effects of the white rot fungus (*Pleurotus ostreatus*) on the physical and chemical properties of beech wood over an *in vitro* 30–120 day exposure time to the given fungus. They reported that the fungus could significantly but gradually reduce wood mass and density due to the enzymatic mechanism by which the fungus could degrade the chemical compounds of wood. The results of another research conducted by Bari et al. (2018) on the *in vitro* effects of two white rot fungi, namely *Pleurotus ostreatus* and *Trametes versicolor*, on the structural properties of beech wood cell walls showed a considerable weight reduction of about 15–18% just after one month of fungal exposure, compared to the 26% weight reduction observed after 4 months. On the other hand, Valette et al. (2017) studied the effects of wood-decaying fungi on wood extractives and elucidated that wood extractives play a key role in increasing the natural durability of wood and in preventing its degradation by white rot fungi.

Over the recent decades, there have been extensive researches on the organic compounds of different wood species across the world, and their mechanical (Woodcock, Shier 2003; Yang et al. 2010), physical (Bektaş et al. 2002), and chemical (Teraziniz et al. 2002; Flaviano et al. 2008; Papadopoulos 2008) properties have been well investigated. Also the effects of short-term (up to 4-month) fungal decay on some wood species have been reported to some extent. To the best of the authors' knowledge, there has been so far no documented publication on the physicochemical properties of decayed oriental beech stumps in a 25-year decay period (after felling) or on the effects of the resulting fungal decay on the obtained pulp properties.

The main hypothesis of the present research was that the decayed beech stumps can serve as an inexpensive and potential alternative for conventional tree logs used for producing wood pulp; this is advantageous in terms of both economic savings and environmental restraints. To investigate the given hypothesis, the aims of this research were to (1) measure the amounts of beech (*Fagus orientalis*) organic compounds, i.e. extractives, holocellulose, and lignin, over a 2–25-year decay period, (2) evaluate the physical properties (density and mass) of decayed beech stumps, (3) investigate the

https://doi.org/10.17221/93/2018-JFS

effects of long-time fungal decay on the properties, in particular pulp yield and Kappa number, of the pulp obtained from the beech stands of Guilan province, Iran, and (4) determine the most important parameters (i.e. lignin and cellulose) affecting the Kappa number, an indicator for pulp bleachability, and thus the kind of probable dominant wood rot fungi existing in the studied region using a multivariate regression analysis.

MATERIAL AND METHODS

Plant materials. To conduct the research, the samples of oriental beech stumps were taken from the Hyrcanian forests of Talesh, Guilan province (longitude and latitude of 48°48' and 37°37', respectively) in June 2014 (Fig. 1). Thirty-six stumps (six for each age group) were randomly selected from the trees felled in 1989, 1995, 1999, 2003, 2009, and 2012, and transferred to the laboratory.

To date the studied stumps, the forest plan booklet of the study region was used, so that after determining the exploited parcels in the given years, beech stumps (diameters of 60–80 cm), having similar conditions in terms of land slope and geographical direction, were selected from the mentioned parcels. To note that the mentioned stumps held grade one quality based on the data extracted from the forest plan booklet. The samples were then cut into disks of 5 cm thickness.

Determination of chemical compounds. To separate and determine the amounts of wood polymer constituents, 60-mesh wood flour was prepared and maintained in vacuumed plastic bags. To obtain extractive-free wood flour from each age group, the extractive materials were isolated and extracted (Eq. 1) according to TAPPI T257 Om-85 standard (Fig. 2). The resulting flour was ultimately oven dried at 103°C ± 2 for 24 h to determine its cellulose (Eq. 2), hemicellulose (Eq. 3) and Klason lignin (Eq. 4) contents according to TAPPI T17 wd-70, TAPPI T249 cm-85 and TAPPI T222 om-02 standards (Bari et al. 2015).

$$\% = \frac{\text{Amount of extractives}}{\text{Total amount of wood biomass}} \times 100 \quad (1)$$

$$\text{Cellulose } \% = \frac{\text{Oven dry weight of cellulose}}{\text{Oven dry weight of extractive free powder}} \times 100 \quad (2)$$

$$\text{Hemicellulose } \% = \frac{\text{Oven dry weight of hemicellulose}}{\text{Oven dry weight of extractive free powder}} \times 100 \quad (3)$$

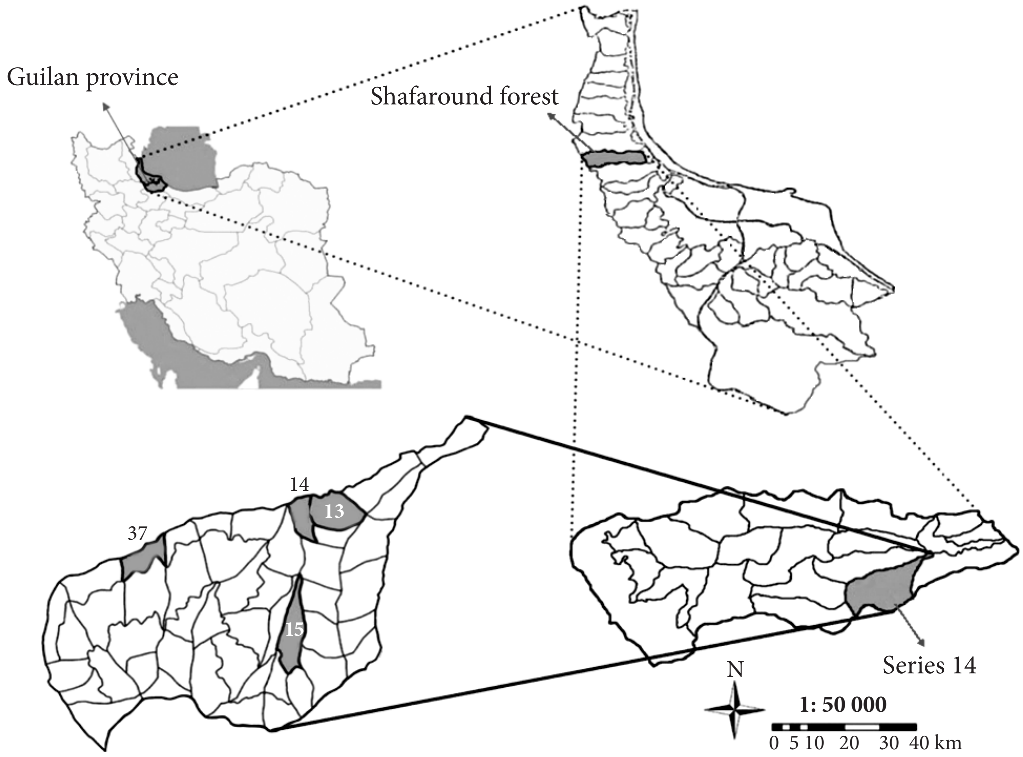

Fig. 1. The studied region (Guilan province, Shafaroud forest, Talesh city – Hyrcanian forests: study sites)

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$$\text{Lignin \%} = \frac{\text{Oven dry weight of powder remaining on filter paper}}{\text{Oven dry weight of extractive free powder}} \times 100 \quad (4)$$

Determination of pulp yield and Kappa number. To determine pulp yield and Kappa number, the studied beech stumps were cut into wood chips of 10–30 mm length and 2–5 mm thickness (Fig. 2) by a sub-industrial wood chipper (Maier Co., Heidenheim Germany).

For each treatment, 100 g of oven dry chips were weighed and added to Kraft cooking liquor (Na_2S = 16.7 g, NaOH = 14.14 g) with a 1:4 wood/liquor ratio.

Pulping was carried out at a maximum temperature of 180°C for 60 min. After washing the obtained pulp with distilled water, it was air dried at ambient temperature. The obtained pulp yield (Eq. 5) was ultimately calculated according to equation 3. To note that the Kappa number (Eq. 6) of the sample pulps was determined according to TAPPI T236 om-99 standard methods.

$$\text{Pulp yield \%} = \frac{\text{Oven dry weight of}}{\text{Oven dry weight of wood chips}} \times 100 \quad (5)$$

$$\text{Kappa number} = \frac{p \times f}{w}\,(1 + 0.013\,(25 - t)) \quad (6)$$

where:
f – correction factor,
t – ambient temperature upon titration,
p – calculated by subtracting the amount of thiosulfate used for pulp bleaching from that used for bleaching pulp-free blank specimen,
w – weight of moisture-free pulp in the specimen (g).

Statistical analysis of data. After normalization of data (using a logarithmic function) and after the homogeneity test of variances, one-way analysis of variance (ANOVA) was used to compare the properties of the studied wood stumps and their resulting pulps, and multiple comparisons of differences in means were done by Duncan's multiple range test at different levels of probability ($P \leq 0.05$, 0.01 and 0.001). To determine the main factor (independent variable) affecting the amounts of the specimen chemical compounds as well as the obtained pulps (dependant variables), stepwise multivariate regression analysis was used.

Spearman's correlation test was also used to establish relationships between the physical and chemical properties of wood stumps as well as the chemical properties of their resulting pulps. All the calculations were carried out by SPSS software (IBM, Armonk, USA).

RESULTS AND DISCUSSION

Variations of physical parameters of beech stumps over a 25-year study period. Results of the analysis of variance indicate that all the physical properties of wood specimens are affected by the stump felling time, having statistically significant differences with one another (Table 1). The wet and dry weights of wood specimens decreased as the felling time of their respective stumps increased, so they decreased from 23.6 and 18.3 g to 7.9 and 5.3 g, respectively. Also, dry and wet densities of the stumps underwent reductions of 64.7% and 66.6%, respectively, over the studied period.

Figs 3 and 4 illustrate that as the felling time of the stumps increases from 2 to 25 years, the wet and dry weights (Fig. 3) as well as the wet and dry apparent densities (Fig. 4) of the studied oriental

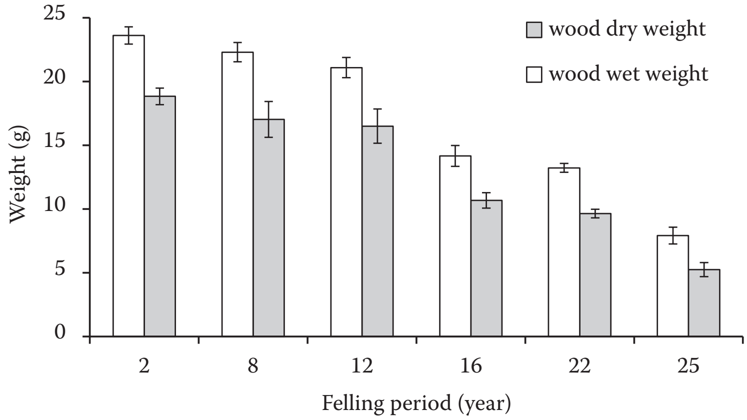

Fig. 2. Wet and dry weights of the studied beech stumps over a 25-year felling period (mean±SD)

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Table 1. The results of one-way ANOVA for the physical parameters of beech stumps over a 25-year period

Physical properties of wood	SS	df	MS	*F*	Sig.
Wet weight	3885.50	5	777.10	40.18	0.000
Wet apparent density	2.97	5	0.60	2346.12	0.000
Dry weight	2545.10	5	509.02	40.91	0.000
Dry apparent density	2.04	5	0.41	1996.66	0.000

Table 2. Results of one-way ANOVA for the chemical parameters of stumps over a 25-year period

Chemical properties of stumps	SS	df	MS	*F*	Sig.
Extractives	16.797	5	3.359	262.52	0.000
Cellulose	1328.790	5	265.758	174.44	0.000
Lignin	105.447	5	21.089	24.82	0.000
Hemicellulose	316.290	5	63.258	83.18	0.000
Holocellulose	2907.176	5	581.435	299.93	0.000
Total mass	4550.045	5	910.009	282.58	0.000
Kraft pulp yield	877.887	5	175.577	291.73	0.000
Kappa number	5.934	5	1.187	79685	0.000

beech stumps decrease due to the degradation of wood organic constituents by the ambient fungi. This is in line with the findings of Christensen (1984), who reported that there was a direct relationship between the weight reduction of wood and its relative density after fungal decay.

Harmon et al. (2001) revealed that wood decay follows an exponential reductive algorithm for wood density, mass, and volume. Tomak (2014) reported the weight loss of wood species brought about by brown-rot fungi to the structural properties of oriental beech and Scottish pine wood as well as their inherent natural durability. However, none of the above-mentioned researches was focused on the assessment of the physicochemical changes of oriental beech stumps over a very long period of fungal degradation (2–25 years).

Results of the one-way analysis of variance (Table 2) indicate statistically significant differences ($P < 0.01$ level) between the amounts of the chemical compounds and/or variables present in the stumps (i.e. the percentages of cellulose, hemicellulose, lignin, extractives and the total percentage of chemical compounds) over a 25-year felling period as well as in the Kappa number and screen yield of the resulting Kraft pulps over the given period. To note that the mean contents of cellulose, hemicellulose, lignin, and total mass of carbohydrates present in healthy oriental beech wood are 39.6%, 28%, 22.2%, and 67.6%, respectively (Bari et al. 2018).

Fig. 4 shows that the amounts of the different chemical compounds present in decayed stumps diminish as their felling periods increase from 2 to 25 years. This is accompanied by a reduction of the resulting pulp yields and Kappa numbers in the given period.

As observed in Fig. 4, the total mass of carbohydrates present in the stumps was reduced by 30% after a two-year felling period, leaving 70% of the chemical compounds intact. The given reduction rose to 60 wt% after 25 years. Fig. 4 also illustrates that the degradation of chemical compounds due to the fungal attack has a rising trend in the felling period concerned. The amounts of cellulose (45.7%) and hemicellulose (55.7%) reductions are higher than that of lignin (27.1%) over the study period, which can probably be due to the presence of brown and soft rot fungi (degrading mainly cellu-

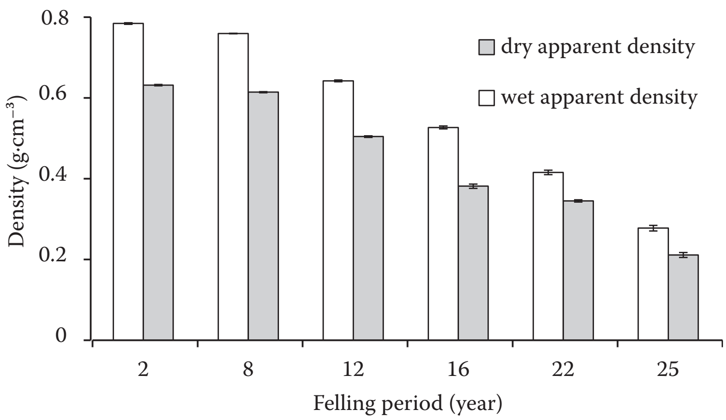

Fig. 3. Wet and dry apparent densities of the studied beech stumps over a 25-year felling period (mean±SD)

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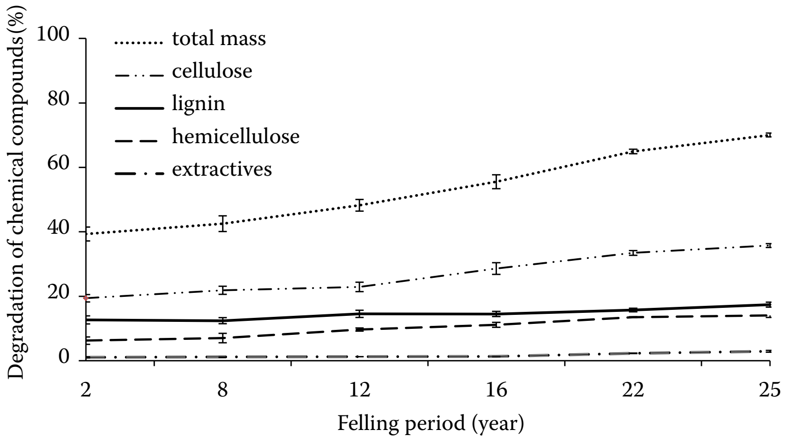

Fig. 4. Degradation percentages of chemical compounds in decayed 2–25-year felled beech stumps (mean±SD)

lose by their cellulase enzyme) as dominant fungal species (*vs.* white rot fungus) in the Hyrcanian forests of Talesh, Guilan province. However, further researches need to be carried out on the kinds and abundance of fungi living in the studied region.

The reason behind the higher degradation rate of hemicellulose (*vs.* cellulose) probably lies in the structure of hemicellulose containing heteropolysaccharide compounds (Kubicek 2013). One of the functions of hemicelluloses is protecting the cellulose microfibrils by providing physical barriers against hydrolytic enzymes. Thus, removal of the hemicellulose components from the cellulose microfibrils facilitates access of fungal hydrolytic enzymes to cellulose (Yang, Wyman 2004). Since the arabinan and galactan are side chain elements of xylan and mannan, they are very prone to degradation (Timell 1967). It can be suggested that they may be attacked before and thus to a higher extent than the main chain of the polymer (i.e. cellulose).

As illustrated in Fig. 4, the highest and the lowest degradation percentages of total chemical compounds were observed in 25- and 2-year decayed stumps, being 70.04% and 39.32%, respectively, and showing that the mentioned carbohydrates were more severely degraded after longer exposure times to ambient microorganisms.

Fig. 6 shows that lignin content decreases after longer exposure times to ambient conditions. Lignin content has a direct relation with Kappa number as it refers to the amount of residual lignin after pulping. As observed in Fig. 5, the yields of Kraft pulps obtained from 2- and 25-year decayed stumps were 22.5% and 8.4%, respectively, evidencing the higher degradation of wood carbohydrates in longer fungal exposure times. Bari et al. (2015) reported that wood rot fungi can colonize the cell lumina of oriental beech and attack the cell walls by thinning the cell walls and creating bore holes on the walls to penetrate through the lumina into

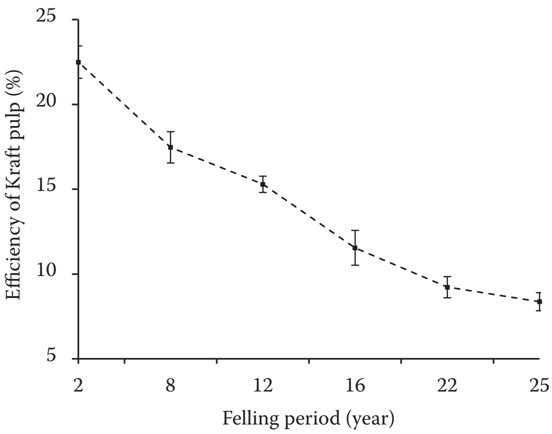

Fig. 5. Effect of beech stump felling period on the resulting pulp yields (mean±SD)

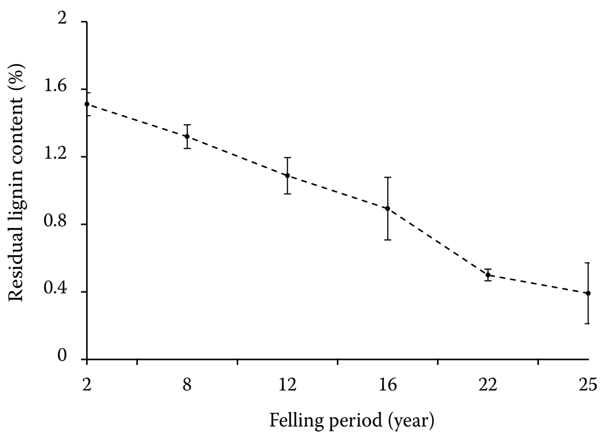

Fig. 6. Effect of beech stump felling period on the residual lignin contents of resulting pulp (mean±SD)

https://doi.org/10.17221/93/2018-JFS

wood. This, in turn, leads to the gradual degradation of wood chemical compounds exacerbated by the pass of time (that increases in the course of time). However, they studied the fungal degradation of beech wood over an exposure period of 4 months. As illustrated in Fig. 6, longer exposure times led to lower percentages of the obtained pulp residual lignin. The highest and the lowest amounts of pulp residual lignin were for 2- (1.5%) and 25-year (0.4%) wood samples, respectively. Wood rot fungi are amongst the biodegradative factors abundantly present in forests which depend on wood and other lignocellulosic resources for their sustenance. The mentioned fungi are classified into three main groups of white-, brown- and soft-rot fungi (Singh 2012; Singh, Singh 2014). Generally, brown- and soft-rot fungi hold the potential to selectively attack cellulose and hemicellulose, whereas white-rot fungi, besides more specifically attacking the lignin polymer, can degrade cellulose and hemicellulose to a lower extent. Brown-rot fungi bring about a marked degradation and/or weight loss that is the reason for failure in wood structures. They selectively decay the carbohydrates (holocelluloses) present in the wood cell walls, leaving behind a modified brown-coloured, demethoxylated lignin residue via Fenton chemistry (Tomak 2014).

Thus, since the results of the present research reveal that the intensities of cellulose (45.7%) and hemicellulose (55.7%) reductions are higher than that of lignin (27.1%), it can be safely concluded for the first time that besides white-rot fungi, brown- and soft-rot fungi play a significant role in decaying the wood biomass existing in the Hyrcanian forests of Talesh, Guilan province, Iran.

Fig. 4 also illustrates that the amounts of chemical compounds including cellulose, hemicellulose, lignin, and extractives were gradually reduced over the entire 25-year study period due to the degradative potential of ambient wood-decaying factors. This, in turn, brought about relative weight reductions in the studied wood specimens. This could be attributed to the nature of enzymes. It is reported that brown-rot fungi tend to degrade both the amorphous regions of cellulose (being more readily degradable) and the harder to biodegrade crystalline regions due to their full enzyme complement containing endoglucanases, glycosidases, and exoglucanases (Timell 1967; Yang, Wyman 2004; Kubicek 2013; Bari et al. 2018).

Similar results were also reported in the existing archival publications (Dare et al. 2010; Nadali et al. 2010; Tomak et al. 2014; Fonseca et al. 2014; Bari et al. 2015; Bari et al. 2018). However, the above-mentioned studies were mainly focused on short-term exposure of wood species to fungal degradation.

Also, the extent of lignin (27.1%) and extractive (35.7%) degradation is lower due to their complicated chemical structures, phenolic compounds, lower hygroscopicity as well as the antifungal mechanisms of wood extractives such as their metal and free radical scavenging roles, direct interaction with the enzymes produced by fungi, perturbation of membrane integrity and disruption of ionic homeostasis. The results indicate that the main reason for the low degradation rates of the above-mentioned wood constituents is attributed to their respective antibacterial and antioxidant properties. This, in turn, leads to improved natural durability of wood against the fungal attack (Li et al. 2014; Sablík et al. 2016; Valette et al. 2017; Bari et al. 2018). Yet, more research needs to be done on long-term, like in the present study, exposure of wood species to the fungi existing in the study area.

As observed in Figs 5 and 6, the fungal degradation of the studied oriental beech resulted in the reduction of pulp yield (62.8%) as well as pulp residual lignin content (74.2%), when the latter is also referred to as pulp Kappa number (Naghdi et al. 2008; Dare et al. 2010; Fonseca et al. 2014; Bari et al. 2015; Navalainen 2017; Tavares et al. 2017). Wood-decay fungi, in particular white rot fungi, can degrade lignin present on fibre surfaces and it can lead to wider accessibility of cooking liquor to the hydrophilic cellulose chains and, in turn, swelling of the decayed wood species (Fonseca et al. 2014; Silva et al. 2016). Application of the given fungi as a pre-bleaching treatment of wood can minimize the contaminant chemicals resulting from both Kraft pulping process (e.g. toxic sulphurous compounds) and pulp bleaching (e.g. toxic chlorinated compounds such as dioxins and absorbable organic halides). Therefore, the decayed beech stumps of the mentioned regions of Hyrcanian forests can be considered as a proper alternative feedstock for pulp and paper production rendering the above-mentioned advantages over the conventional raw materials used for pulping (Marcial et al. 2010; Naghdi et al. 2013; Fonseca et al. 2014; Navalainen et al. 2017; Woldesenbet et al. 2017).

https://doi.org/10.17221/93/2018-JFS

Table 3. Results of stepwise regression analysis of the main chemical parameters (independent variables) affecting the Kappa number (dependent variable)

R^2	F	Regression equation	Model
0.801	136.56	$Y = -0.70 + 0.06$ Cellulose	1 UC[a]
		$Y = 0.89$ Cellulose	1 SC[a]
0.832	81.58	$Y = -1.23 + 0.04$ Cellulose + 0.07 Lignin	2 UC
		$Y = 0.63$ Cellulose + 0.32 Lignin	2 SC

UC[a] – Unstandardized coefficients; SC[a] – Standardized coefficients; *Y*– Kappa number

Kappa number modelling. To determine the most important parameters (i.e. lignin and cellulose) affecting Kappa number, an indicator for pulp bleachability, and thus the kind of probable dominant wood rot fungi existing in the studied region correspondingly, a stepwise multivariate regression analysis was used. The results of Table 3 demonstrate that the two variables of the percentages of cellulose and lignin could fit in the mentioned regression analysis. In the first step, the percentage of cellulose was the only variable inserted in the equation ($P = 0.00$, $F = 136.6$, coefficient of determination, i.e. $R^2 = 0.80$). In the second step, the percentage of lignin was, in addition to that of cellulose, inserted in the equation ($P = 0.00$, $F = 81.6$, $R^2 = 0.83$). The given results indicate that Kappa number, an indicator for pulp bleachability, has a tight relationship with the percentages of cellulose and lignin. In other words, it is possible to calculate the value of Kappa number using the mentioned variables. To note that it was expected that the percentage of residual lignin would be more effective than that of cellulose on the Kappa number model due to the direct relationship of pulp residual lignin and Kappa number. It is assumed that cellulose content cannot be significantly effective on Kappa number unless cellulose is highly degraded by wood-rotting fungi which need to initially degrade the interfacial and/or superficial lignin layer to reach cellulose microfibers. As the extent of cellulose degradation is significantly higher than that of lignin (Fig. 4), it can be concluded that based on the presented model, the percentage of cellulose is more effective on Kappa number compared to that of residual lignin.

Thus, the model demonstrates that cellulose content is not only effective for estimating Kappa number but also it has a greater share in modelling Kappa number than lignin content. This also demonstrates the dominance of brown rot fungi in the studied region, as compared to the other kinds of wood-decaying fungi reflected by the higher degradation of cellulose (*vs.* lignin) in the decayed stumps of oriental beech collected from the studied area of Hyrcanian forests. However, there has been so far no documented research reporting the amount of different wood-rot fungi existing in the studied region, which calls for further studies should the role of each kind of fungi (e.g. white, brown, and soft rot) be precisely mentioned in wood decay.

CONCLUSIONS

The present study was focused on measuring the amounts of cellulose, hemicelluloses, lignin, and extractive compounds of oriental beech stumps felled from the Hyrcanian forests of Talesh, Guilan province, Iran over a 25-year decay period as well as their respective pulp properties, e.g. pulp yield and Kappa number. The results showed that the carbohydrates of beech wood such as cellulose and hemicelluloses, the main components of pulp and paper products, underwent higher degradation levels as compared to lignin and extractives having antifungal compounds. This evidences that besides white rot fungi, brown and soft rot fungi, mainly degrading wood cellulose, play a significant role in decaying the wood species existing in the mentioned forest areas. The degradation of the chemical compounds of beech stumps resulted in the reduction of the obtained pulp yield (62.9%) and Kappa number (74.2%) over the study period. This demonstrates the substantial degradation of carbohydrates and, to a lower extent, lignin by fungal decay. Degradation of lignin and extractives brings about the lower consumption of chemicals required for pulping and further bleaching processes. This, in turn, leads to reduced environmental contamination produced by the mentioned chemicals such as chlorinated and sulphurous compounds. Furthermore, it was elucidated by regression modelling that Kappa number, in addition to lignin content, can be tightly related with cellulose content due to the excessive cellulose degradation of the studied beech stumps. The presented regression model can, in effect, show the intensity as well as the combined and simultaneous effect of both lignin and cellulose contents on the Kappa number of the obtained pulp.

https://doi.org/10.17221/93/2018-JFS

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