Middle-East Journal of Scientific Research 8 (5): 921-926, 2011
ISSN 1990-9233

Effect of Altitude on Fiber Characteristics, Chemical Composition and Efficiency of *Eldar pine* Kraft Pulp

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Abstract: This research was implemented to study the effect of altitude on fiber characteristics, chemical composition and efficiency of Kraft pulp in eldar pine. Sampling was done for three altitudes of 500, 700 and 900 m in Marzanabad site. Three healthy eldar pines were cut in each elevation. Fiber maceration was followed by Franklin method while measuring the fiber characteristics was done through Image Analyzer. Chemical composition cellulose, lignin, ash and extractive material from the eldar pine were examined in accordance to TAPPI standard. Kraft pulp was produced with active alkalinity in two levels of 15% and 20% and three different time durations of 50, 70 and 90 min. Variance analysis in based on a completely randomized design, Duncan test and Factorial experiment were employed for measurement of fibers and chemical composition, comparison between the averages and kappa number and efficiency of the pulp, respectively. Obtained results indicated 5% statistical significance in reliability level for the eldar pine from three altitudes of 500, 700 and 900 m in terms of fiber characteristics of early wood and latewood. Thereby, samples of 700 and 900 m had the highest and the lowest values, respectively. In terms of chemical composition, the eldar pine from 700 m elevation contained more cellulose in 5% reliability level whereas the sample from 900 m altitude included more lignin and extracted materials in 5% reliability level; however no difference was reported for ash contents from the three altitudes. The pulp associated with 900 m elevation seems to be more convenient to produce a more resistant bleachable pulp. Provided that an appropriate refining is done on the fibers, it will be possible to use pulp of eldar pine from 700 m altitude due to its higher efficiency to make various paper products such as carton, Kraft liner and package papers.

Key words: Altitude · Eldar pine · Latewood · Kraft pulp · Kappa number

INTRODUCTION

Significant dependence on wood, wood products and paper in addition to increasing trend in need and consumption of the wood, while there is lack of cellulosic and forestry resources, have altogether provoked wood and paper researchers and scholars to study on utilization of suitable species. Besides acclimation, these species should have an appropriate structure in terms of chemical composition and fibers to prepare pulp to be usable in the pulping industry. Most strength properties of the paper bear close relevance to length of the fibers included. Hardwoods have shorter fibers among wood species, so whenever a paper is produced from hardwood fibers, it will not be possible to provide the desired strength. To solve this problem, factories always add definite percentage of softwood species to hardwood pulps. Unfortunately, there are very little sources of softwoods in Iran and one must regularly import softwood pulp containing longer fibers from other countries which is accompanied with noticeable amount of currency leaving the country. In order to solve this issue, there is no other solution except focusing on the existing capabilities and their protection and development [1]. On the other hand, softwood species can be planted and utilized in many lands where are impossible to grow hardwoods because of lower biological requirements than hardwoods. Therefore, different softwood species (specially pines) have been imported from foreign countries and planted experimentally in Zagros district and northern districts such as Kolaleh most of which have yielded successful results [1]. Since a great deal of currency is spent to import long fiber pulp as well as various papers from the foreign countries, it should be adopted to develop planting or cultivating wood in different regions wherever possible [1].

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In another research, effect of planting location on the amount of brutian wood was assessed in Antalya countryside, Turkey which yielded the following results: base density or critical density (ratio of the weight of completely dried wood to the volume of completely wet wood) for the brutian pine wood was 0.476 g/cm^2 with the base density being decreased along the length of tree towards the upper stalks. Efficiency of the dried material related to three planting classes of good, fair and poor was evaluated on 40, 44 and 56 years old trees for the abovementioned locations. It was estimated that the averaged yearly increase of the maximum dried material was 0.977, 0.775 and 0.634 tons/hectare for good, fair and poor lands, respectively. They have also argued that the planting conditions can affect chemical composition and quality of the paper-making properties of the woods [2].

It was declared in another study that major differences may be avoided in the produced wood if different planting lands are selected close to each other while farther sites can make significant differences. For example, a tree of higher latitudes which is grown in the highlands usually has lower density and shorter fibers than a tree grown in the lowlands [3].

In a study on morphological properties of fibers, chemical composition and resistance properties of the pine Kraft pulp have explored that the brutian pine is convenient to be used in pulp and paper industry [4].

In this research effect of altitude on fiber characteristics, chemical composition and Kraft pulp production has been studied for the eldar pine planted in Marzanabad.

MATERIALS AND METHODS

Sampling was done in three altitudes (500, 700 and 900 m) from Marzanabad located in Chalous, Iran. In order to prepare desired samples to measure fibers dimensions, chemical composition analysis and producing the pulp, 1.2 m length sections were picked from cut woods (with equal diameter of heart). Disks with 2 cm thickness were prepared from equal hear height to measure dimensions of the fibers. A wood strip of 1 cm width was also obtained from each disk. Additionally 5 cm thick disks were cut for chemical composition analysis. Other samples were also used to produce Kraft pulp.

Franklin technique was employed to measure dimensions of the fibers, in which a 2 cm thick disk of the same heart diameter was cut from each log as well as a wood strip [5]. Choosing the wood strip was such that it included all yearly growth rings. Wood chip was obtained from earlywood and latewood using microtome, then earlywood and latewood of trees from three different altitudes were mixed together. Afterwards, 1:1 mixture of citric acid and 20% oxygenized water was placed in oven at 60°C for 48 hours for the purpose of unlocking the fibers. Samples were extracted from the oven and rinsed with distilled water to neutralize the effect of both acid and oxygenized water. At the end, some distilled water was added to the test tube and some droplets of Zaffranine solution was added to it. For unlocking the fibers from each other, the test tube was shaked vigorously. From earlywood and latewood of each ring, some 30 fibers (fiber length, fiber diameter, hole diameter and wall thickness) were measured. Measurement of the extracted material was implemented based on T204cm-97 standard from TAPPI (Technical Association of Pulp and Paper Industries) with three runs for each test. Wood chip was produced and then mixed using the remaining 60cm logs which were obtained from 1.2 m height of tree. Some 100g dry weight of wood chip was used for each cooking process. Ratio of cooking liquid to wood was selected as 4:1. Liquid sulfidity and cooking temperature were chosen as constant value of 25% and 160°C, respectively. eldar pine woods with two levels of active alkali (15 and 20%) were used to make the pulp while the cooking time was considered 50, 70 and 90 min. In order to determine the optimal pulp, efficiency and kappa number were also considered. In this study, parameters of alkalinity level, time and altitude were mentioned in 2, 3 and 3 levels, respectively. Three times cooking caused to have 54 total cooking procedures. Finally, rinsing process was followed by unlocking the fibers using laboratory defibrillator and the pulp was collected on the filters after being screened. The obtained pulp was air-dried at room temperature at least for some 24 hr. Weight of the air-dried pulp was measured and it was kept in a airtight plastic bag. In order to determine moisture of the air-dried pulp, part of it was dried in oven at 100°C for 24 hr after being weighed. By calculating the moisture percentage, dry weight and the efficiency, measuring the kappa number was implemented in accordance to T236om-99 standard of TAPPI [6-7]. Variance analysis was employed to measure dimensions of the fibers and their chemical composition based on a completely randomized design in order to compare averaged values of Duncan test while Factorial experiment was conducted again based on a completely randomized design to measure pulp efficiency and kappa number.

Table 1: Statistical comparison on fibers characteristics for the earlywood obtained from eldar pine (from three regions with different altitudes)

Source of variation	Freedom degree	Calculated F fiber length	Calculated F fiber diameter	Calculated F pit diameter	Calculated F Fiber wall thickness
Treatment	2	66.732^{ns}	55259.763*	23151.485*	843.250*

*statistically significant on 5% reliability, ^{ns}not significant on 5% reliability

Table 2: Statistical comparison on fibers characteristics for the latewood obtained from eldar pine

Source of variation	Freedom degree	Calculated F fiber length	Calculated F fiber diameter	Calculated F pit diameter	Calculated F Fiber wall thickness
Treatment	2	93.295^{ns}	21816.600*	194.498*	214.333^{ns}

*statistically significant on 5% reliability, ^{ns} not significant on 5% reliability

Table 3: Fibers characteristics for the early wood obtained from eldar pine

Altitude (m)	Fibers length (μm)	Fibers diameter (μm)	Pit diameter (μm)	Wall thickness (μm)
500	3.22	44.31	34.25	5.03
700	3.26	51.30	40.52	5.39
900	2.94	42.03	32.59	4.72

Table 4: Fibers characteristics for the latewood obtained from eldar pine

Altitude (m)	Fibers length (μm)	Fibers diameter (μm)	Pit diameter (μm)	Wall thickness (μm)
500	3.34	41.51	28.39	6.56
700	3.73	43.70	29.78	6.96
900	3.26	37.93	24.95	6.49

Table 5: Variance analysis on the extractive materials soluble in acetone alcohol, cellulose and lignin obtained from eldar pine

Source of variation	Freedom degree	Calculated F extractive materials	Calculated F ash	Calculated F Cellulose	Calculated F lignin
Treatment	2	27.136*	27.136^{ns}	24821.233*	538.945*

*statistically significant on 5% reliability, ^{ns} not significant on 5% reliability

RESULTS

Characteristics of the Fibers in Eldar Pine: Results obtained from variance analysis showed that for the eldar pine among three altitudes of 500, 700 and 900 m in terms of fibers diameter, pit diameter and wall thickness of the earlywood and latewood, there is 5% statistical significance in reliability (Table 1 and 2).

Averaged values of measurements on fibers length, fibers diameter, pit diameter and fibers wall thickness associated with the eldar pine wood in three elevations of 500, 700 and 900 m has been summarized in Tables 3 and 4. It can be observed that 700 and 900 m altitudes have contained the highest and the lowest amounts of fibers, respectively.

Results of the variance analysis unfolded that for the eldar pine among three altitudes of 500, 700 and 900 m in terms of average extracted materials soluble in acetone alcohol, cellulose and lignin; there is 5% statistical significance in reliability (Table 5).

Cellulose: Fig. 1 illustrates the variation in cellulose content for three different elevations. It can be observed that 700 and 900 m altitudes were accompanied with the highest and the lowest amount of cellulose, respectively.

Lignin: Fig. 2 summarizes the variation in lignin content for three different Altitudes. It can be observed that 900 and 700 m altitudes were accompanied with the highest and the lowest amount of lignin, respectively.

Extracted Soluble in Acetone Alcohol: Fig. 3 has summarized changes in the extracted materials soluble in acetone alcohol for three elevations. It can be observed that altitudes of 900 and 700 m have the highest and the lowest amount of extracted materials which are soluble in acetone alcohol, respectively.

Ash: Fig. 4 shows the variation in amount of ash for three different elevations. It can be observed that altitudes of 700 and 900 m have the highest and the lowest amount of ash, respectively.

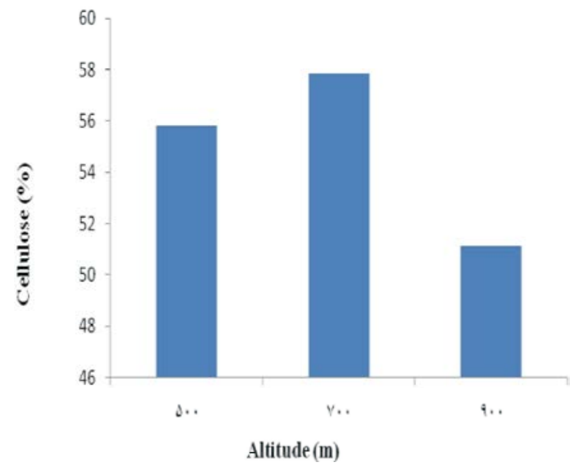

Fig. 1: Variation in cellulose content for the eldar pine

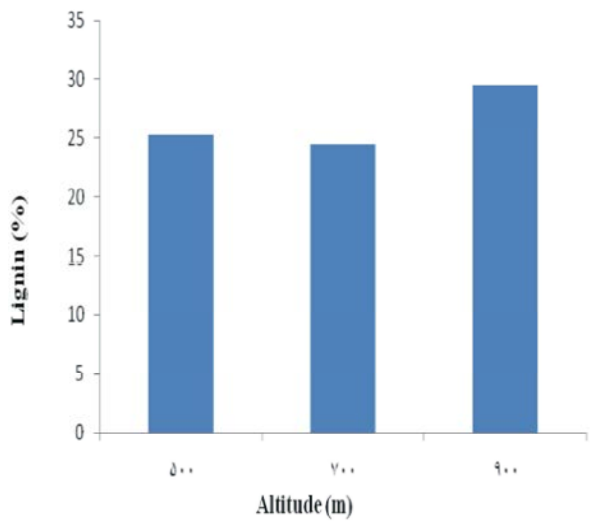

Fig. 2: Variation in lignin content for the eldar pine

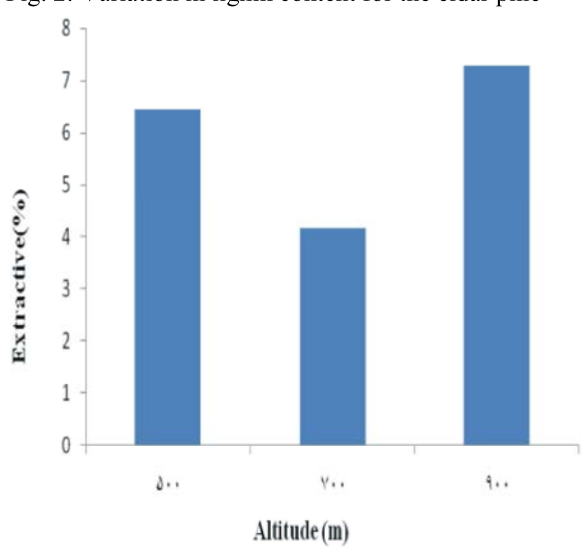

Fig. 3: Variance analysis on the extracted soluble in acetone alcohol for eldar pine

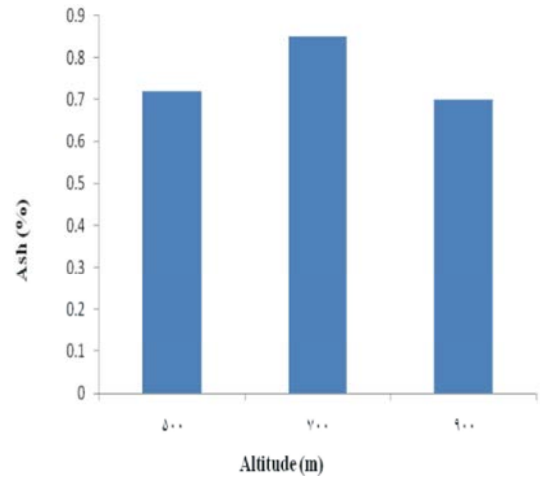

Fig. 4: Variation in ash content for the eldar pine

Pulp Efficiency and Kappa Number: In order to compare the effect of each cooking variable separately and to study the mutual effect of them on the pulp characteristics obtained, factorial experiment in a completely random design was launched. Table 6 summarized the results of variance analysis in terms of cooking variables on pulp efficiency and kappa number. It is evident from the table that independent effect of altitude, cooking time and active alkalinity on the pulp's efficiency and kappa number has been significant in 5% reliability. Meanwhile, the mutual effect of cooking time and active alkalinity on the pulp's efficiency and kappa number, in addition to the mutual effect of elevation and active alkali (AA) on the pulp's kappa number was significant in 5% reliability. But the mutual effect of elevation and cooking time, the mutual effects of elevation, cooking time and active alkali on the pulp's efficiency and kappa number as well as the mutual effect of elevation and active alkalinity on the pulp's efficiency was not significant in 5% reliability.

In order to determine delignification characteristics after each cooking, the pulp's efficiency and kappa number was measured separately for each elevation. Regarding the obtained results it was observed that the highest values of efficiency and kappa number was associated with 15% alkalinity and 50 min cooking time while the lowest values of them was related to 20% alkalinity and 90 min cooking time.

Effect of active alkalinity and cooking time on pulp efficiency of the eldar pine wood in three elevations over Kolaleh region can be observed in Table 7. The obtained results indicated that the pulp's efficiency related to 700 m altitude was more than the other two elevations in same alkalinity and cooking time which was in agreement with the results achieved for chemical composition.

Table 6: Variance analysis test for the effects of cooking variables on the pulp's efficiency and kappa number

Source of variation	Freedom degree	F calculated efficiency	F calculated kappa number
Altitude	2	5937.899*	13123.231*
Cooking time	2	3965.212*	8754.652*
Active alkali (AA)	1	67290.842*	123453.653*
Altitude* cooking time	4	87.321^{ns}	2.543^{ns}
Altitude* active alkali (AA)	2	61.543^{ns}	2315.521*
Cooking time* active alkali (AA)	2	134.532*	213.094*
Altitude* cooking time* active alkali (AA)	4	65.238^{ns}	3.432^{ns}
Error	36	-	-
Total	54	-	-

*statistically significant on 5% reliability, ^{ns} not significant on 5% reliability

Table 7: Effect of active alkalinity and cooking time on total efficiency and kappa number of pulps obtained from eldar pine wood

Altitude (m)	Time (min)	Active alkali (AA)	Averaged efficiency (%)	Averaged kappa number
500	50	15	49.90	73.79
500	50	20	44.42	48.70
500	70	15	47.84	62.90
500	70	20	43.52	40.76
500	90	15	44.64	46.75
500	90	20	42.11	35.90
700	50	15	53.45	90.02
700	50	20	46.93	57.59
700	70	15	48.97	85.87
700	70	20	45.94	56.13
700	90	15	48.52	73.09
700	90	20	43.37	73.09
900	50	15	47.69	67.39
900	50	20	42.40	44.09
900	70	15	42.30	54.34
900	70	20	39.90	39.71
900	90	15	41.49	44.87
900	90	20	38.00	32.19

DISCUSSION AND CONCLUSIONS

Dimensions of the Fibers: Results indicated that the eldar pine wood obtained from 700 and 900 m altitude has had the highest and lowest contents of fibers' dimensions. Taking into account the wider growth rings existent in the eldar pines of 900 m elevation, it can be characterized that these conditions is more suitable for growth. Meanwhile, the latewood in all cases has had larger wall thickness and fiber length although smaller fiber diameter and hole diameter than the earlywood.

Chemical Compounds: The obtained results indicated that the wood of 700 and 900 m altitudes has had the highest and the lowest amount of cellulose, respectively. Because in the eldar wood of 700 m, more cellulose has been formed due to its thicker cell wall; meanwhile lignin content of the eldar pine wood has been measured as 25.27, 24.49 and 29.53% in three altitudes of 500, 700 and 900 m, respectively.

This was in agreement with findings of [8], since in the 900 m elevation eldar pine wood lignin micro-molecules have been formed with shorter chains and higher quantities due to widespread growth and reproduction of cells which has lead to more weights of lignin. On the other hand, the 900 m elevation eldar pine wood has experienced more extracted materials from the trunk due to widespread reproduction of the cells. This level of extracted materials in woods of 900 m altitude can be very important in producing side products of pulp such as tall oil.

Pulping: Based on the achieved results, pulp efficiency and kappa number have been decreased when active alkalinity is increased from 15 to 20%. Because by increasing the content of chemicals, their concentration will raise which lead to higher rate of reaction or higher rate of delignification. This can cause more delignification and destruction of polysaccharides. More cooking time will then decrease efficiency and kappa number.

Results showed that in same active alkali and cooking time, the largest kappa number was related to the pulp of 700 m altitude sample since the eldar pine wood of this elevation has thicker cell wall rather than the other two elevations in spite of lower contents of lignin. Therefore, it has been less affected by cooking conditions and has lost less lignin amounts. As a result, its pulp has shown higher kappa number and because of the significant amount of the residual lignin, it has higher costs of bleaching and whitening. These altogether have made the eldar pine wood from 700 m altitude an extensively used material for producing carton, Kraft liner and package paper. On the other hand, the eldar pine wood from 900 m elevation has lower kappa number because simply loses its lignin due to thin cell wall which makes it more potential to be used in producing bleachable and more resistant papers. Although the obtained paper must be refined well to improve it strength properties, since it contained less cellulose and more lignin.

As the final goal of pulping process is to produce papers with high strength, it is suggested here to conduct further research on strength properties of the prepared paper from eldar pine wood in three altitudes as well as produced paper from hardwood containing mixtures.

REFERENCES

1. Nouri, R., 1999. Study on the possibility of using softwood Kraft pulp from Mazandaran plantation forest (*Pinus brutia* & *Picea excelsa*) instead of imported longfiber pulp for producing different grades of paper in Mazandaran wood and paper industry. M.sc Thesis, Tarbiat Modaress University, pp: 120.
2. Sertmehmetoglu, Z., O. Acar and A.S. Birler, 1968. Some investigation rotation and dry yield from Pinus brutia forests with relation of paper industry in southeastern anatalia. I.U. Orm. Fak. Yayini, 281: 235-236.
3. Zobel, B.J. and J.P. Buijtenen., 1989. Wood variation. Its causes and control. Springer Verlag, Berlin, New York, pp: 250.
4. Bektaş, I., A. Tutuş and H. Erouglu, 1999. A study of the suitability of calabrian pine (*Pinus brutia*) for pulp and paper manufacture. Tr. J. Agric. and Forestry, 23: 589-597.
5. Franklin, G.L., 1954. A rapid method for softening wood for anatomical analysis, Tropical Woods, 88: 35-36.
6. Tappi, 1993. Ash in wood, pulp, paper and paper board: combustion at 525°C. T 211 om-93.
7. Tappi, 1997. Solvent extractives of wood and pulp. T 204 cm-97.
8. Gindlow, W., M. Grabner and R. Wimmer, 2001. Effects of altitude on tracheid differentiation and ignification of Norway Spruce. Holzforschung, 79(7): 815-821.