Extractive Content of European Aspen (*Populus tremula*) Wood after high-temperature Drying

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The main aim of this study was to research the final extractive content of the aspen wood after HT-drying, which was also studied within and along the length of the trees. The dependences were tested with the methods of the regression analysis. Also the effect of the dry content was tested.

The highest extractive content after HT-drying was in the samples cut from the 15 metres height (2.9 %). At the height of the stump the extractive content on average was 2.0 %. In horizontal direction the variation of extractive content was biggest at the heights of 9 and 12 metres, in which the contents decreased rather linearly from the heartwood to the surface. It was not possible to perceive the variation of extractive contents closer to the stump of the tree. The bigger heartwood content of the base may cause this. However, the highest extractive contents were measured quite from the sapwood.

Key words: aspen, extractives, high temperature drying

Introduction

Most of the applied drying systems in Europe are based on conventional kiln drying with temperatures between 40°C and 80°C depending on the wood species. Thus, high-temperature drying (HT-drying) and especially heat-treatment of wood is becoming more common when building new kilns. The advantages of HT-drying compared to conventional drying are connected to saving time and energy; HT-drying takes only one fourth of the time and half of the energy required by conventional lower temperature methods (Maun 1999, Ranta-Maunus 2001). In heat-treatment, wood is heated for 4-8 h in a steam atmosphere at high temperatures (180-250 °C) (Viitaniemi *et al*. 1996).

It has been noticed that heating wood at high temperatures (> 100°C) enchances its ability to resist biological stress caused by fungi and heat treatment has an influence on certain physical properties (e.g. density, strength, dimensional stability, water sorption and colour) in wood. Heat-treated wood is used in the manufacture of wooden products such as outdoor furniture, covering of wooden buildings and musical instruments (Zaman *et al*. 2000)

The extractives of the wood originate mainly from the resin, which dissolves mainly in organic dissolvents, and from different hydrocarbons. In the conifers there is resin of two kinds; physiologic resin of the healthy wood and as consequence of damaging or the infection developing pathologic resin, which is not found in the hardwoods at all. The physical resin consists of fats, waxes and alcohols. The pathologic resin, however, contains different resin acids and some terpens (Voipio *et al*. 1992).

The extractives in wood, bark and leaves have an alike structure in many respects; the contents and quantity relations vary depending on the kind of wood and depending on the part of the tree. The extractives of wood and bark, which dissolve in organic dissolvents, are alifatic hydrocarbons (contain 10-30 carbon atoms), alcohols, fatty acids, waxes, terpen, resin acids and sterol. Some of the extractives, which dissolve in the water, are, among others, some phenols, sugars (saccharose, fructose, glucose, staciose, raffinose) which are free of the carbohydrates, pectin and uronacids; tannin (big molecular phenols) is found mostly in the bark. Their proportion of the extractives of the wood is 10-30 % and that of the bark 15-20 % correspondingly. Some of the extractives which are typical in the green mass (leaves/needles) of the trees are chlorophyls, carotenoids and vitamins which all dissolve in organic dissolvents. In bark and green mass there are also more monoterpens and volatile aromatic hydrocarbons than in the wood. Nearly all these evaporate in the drying stage and their share is not included in the total extractive content (Voipio *et al*. 1992).

The extractives are located in certain morphologic places in the structure of the wood. For example resins are located in resin canals, whereas fats and waxes are located in parenchymacells. Phenols are located mainly in the heartwood and in the bark. The different type of extractives are necessary to maintain the versatile biological functions of the tree. For example, fats form the source of energy of cells; terpenoids, resins and fenols protect the tree from the microbiological damages or insects (Sjöström 1993).

This sub-project is connected to the bigger project in which the purpose is to analyse the technical properties of the aspen timber, quality and suitability for the needs of the mechanical wood processing industry. In the framework allowed by the material it was decided to clarify from the wood samples how the HT-drying affects to the extractive content of the aspen wood. The remaining extractive content has especially an important influence on the ability to resist biological stress caused by fungi. The main aim of this study was to define the final extractive content of the aspen wood after HT-drying, which was also studied within and along the length of the trees. The dependences were tested with the methods of the regression analysis. Also the effect of the dry content was tested.

Material and methods

The research material consisted of ten aspen stems, which had been cut from Pyhäselkä, North Karelia, eastern Finland (62°33□25□□E, 29°49□00□□N) in December, 1996. The trees were 20 metres on an average length and the diameter at breast height (dbh) 28 cm. The age of the trees was on average 37 years and the forest type was MT (*Myrtillus* –type). Four centimetres thick discs were cut after two hours of felling from the stump height and from 3, 6, 9, 12 and 15 metres heights. The discs were frozen in order to prevent drying. Altogether there were 60 pieces of discs. Later 2x2x2 cm samples were sawn from the discs so that from the stump height 8 of them were sawed, 7 pieces from 3 and 6 metres, 6 pieces from 9 metres, 5 pieces from 12 metres and 4 pieces from 15 metres. This way altogether 370 pieces of samples were accumulated. The distribution of samples in the stem is shown in Figure 1.

The HT-drying was simulated in the laboratory scale. Before the HT-drying, the samples were stabilized at 65 % relative humidity. The drying temperature in the simulated HT-drying was up to 105 °C temperature after which cooling down was made. The average final moisture content after HT-drying was close to 4 % (Figure 2). Later, one piece (2 gr.) was cut from the sample. The piece was ground as fine powder. Two, about one gram weight sample each, were made from the powder. From one, moisture percentage was determined and from other the extractive content.

Standardized methods in which the extractives are extracted to an organic dissolvent, such as acetone, are used for the determination of the extractive content of the wood, as also in this study. The extractive

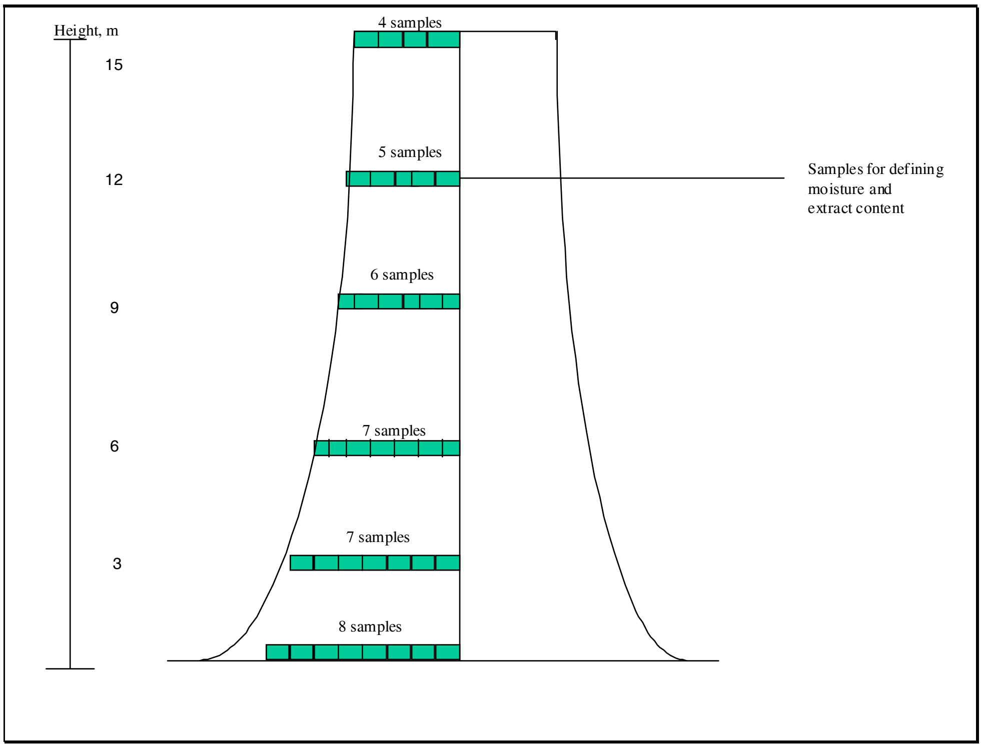

Figure 1. Placing of samples in the stems.

content was determined with a Soxtec -extracting in which technical acetone is used as a dissolvent. The running time for Soxtec was 1 hour 45 minutes.

Results

Moisture percentage, extractive content and dry content of samples were determined from the results that were obtained from the measurings. Figure 2 shows the variation of final moisture percentage and extractive content after HT-drying.

At the height of three meters the extractive content of the wood varies fairly distinctly in the cross section of the tree. The average extractive content is 1.9 %, so, smaller than that at the stump height but the variation seems correspondingly to be slightly bigger. There is also a clear negative dependence between extractive content and dry content at this height. The average dry content in three meters height is 94.32 %.

The results at six meters height are parallel with those at stump height and height of three meters. In the extractive content a variation in the cross section cannot be perceived. The average extractive content is 2.1 % and the average dry content 94.32 %.

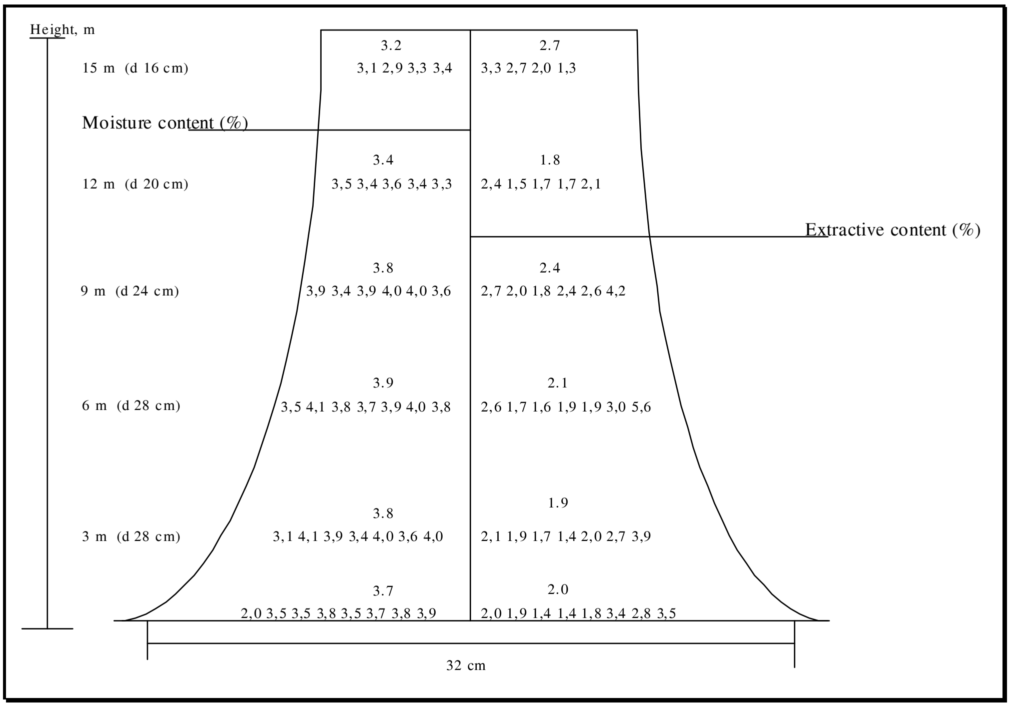

Figure 2. Variation of moisture and extractives after HT-drying in aspen stems.

Figures 3, 4, 5, 6, 7 and 8 show the horizontal variation of the extractive content in the stem at different heights and the variation of the extractive content as a function of the dry content. The horizontal variation has been presented so that with x -axis 1 it means the pith of the tree and the biggest number means the sample next to bark. The significance and the regression coefficients between dry content and extractive content are shown later in Table 1.

The average extractive content on the height of the stump was 2.0 %. The variation is not very wide in the cross section of the stump either; instead the variation is distinctly bigger in the sapwood than in the heartwood. Between extractive content and dry content a clear negative dependence can be perceived. The average dry content on the height of the stump is 94.42 %.

The results at nine meters height are parallel to the lower heights. The average extractive content is 2.4 % and the average dry solids content 93.88 %.

In the twelve meters height, clear variation in the results can be perceived. The extractive content of the heartwood would seem to be slightly higher than that of the sapwood. The average extractive content at this height is 1.8 %. A negative dependence between extractive content and dry content can be seen but it is distinctly smaller compared to the lower heights. The average dry content percentage is 94.81 %.

The results at fifteen meters height are parallel to those at stump, 3, 6 and 9 meters heights. The average extractive content is 2.7 % and the average dry solids content 94.15 %.

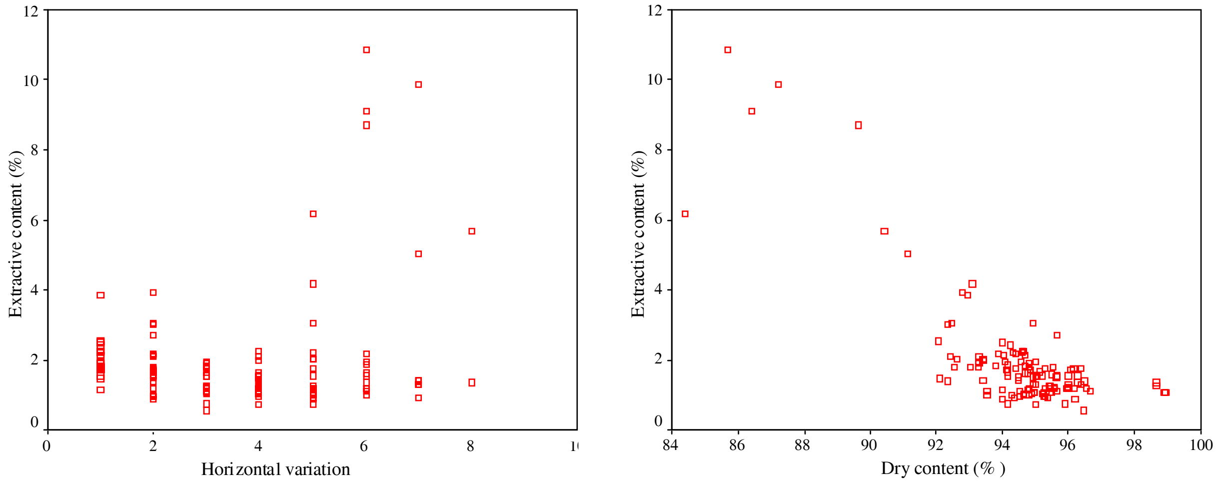

Figure 3. Results from the stump height.

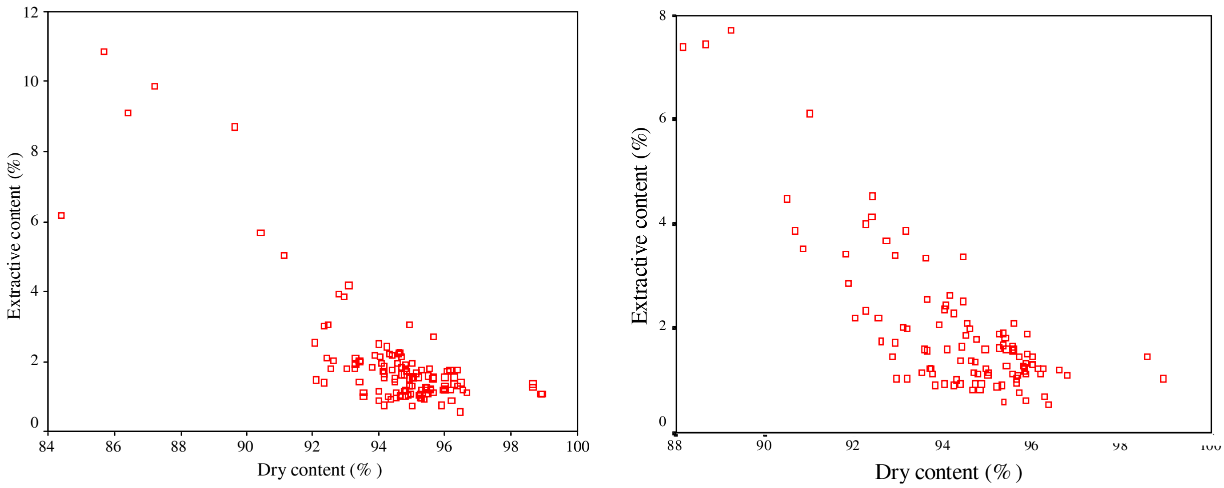

Figure 4. Results from 3 meters height.

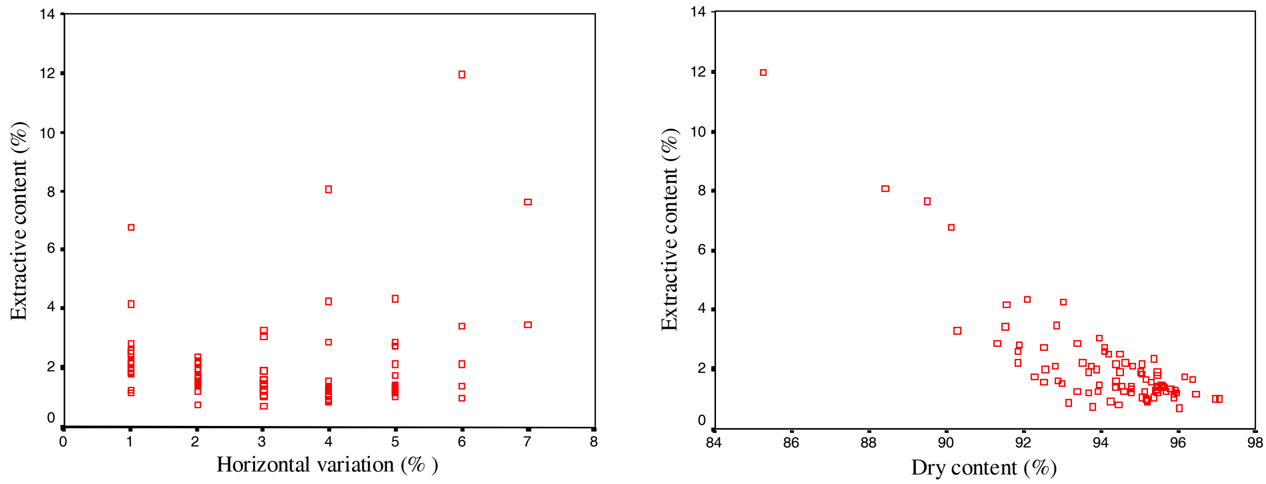

Figure 5. Results from 6 meters height.

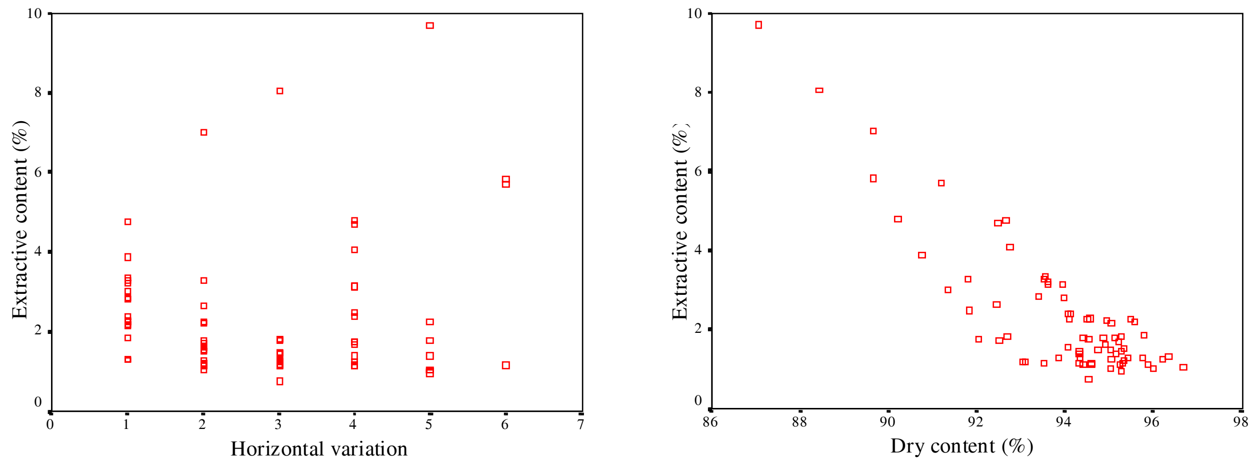

Figure 6. Results from 9 meters height.

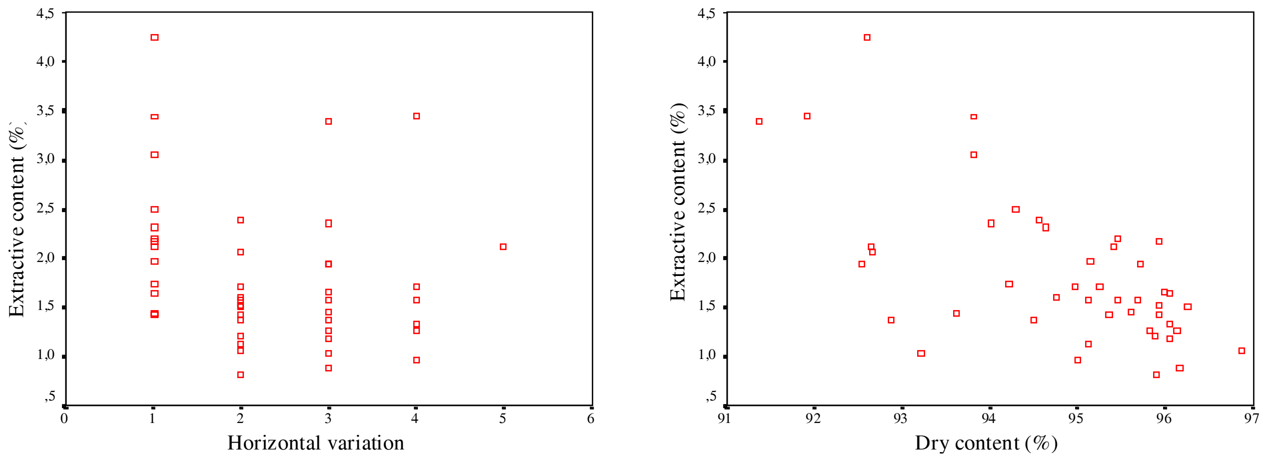

Figure 7. Results from 12 meters height.

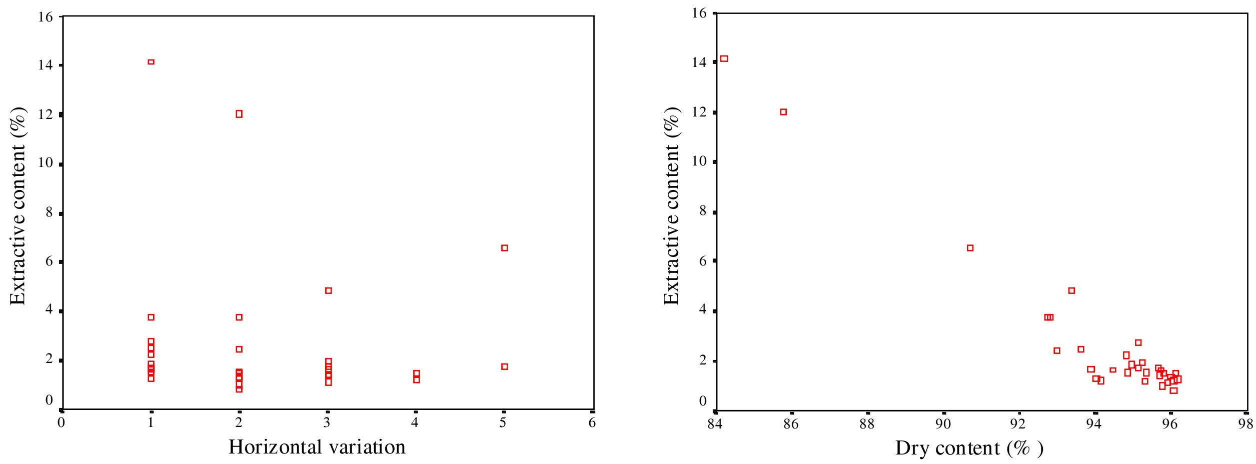

Figure 8. Results from 15 meters height.

Table 1. Results of the regression analysis at different heights of aspen stems.

Height	R	R^2	β	α	s.e.(β)	Sig.
Stump	0.81	0.66	-0.63	61.82	0.04	0.00
3 m	0.79	0.62	-0.61	59.36	0.05	0.00
6 m	0.83	0,69	-0.73	70.73	0.05	0.00
9 m	0.85	0.72	-0.77	74.68	0,06	0.00
12 m	0.63	0.39	-0.35	35.04	0.07	0.00
15 m	0.97	0.94	-1.06	102.13	0.05	0.00

From Table 1 one can notice that on the whole length of the aspen stems, dry content and extractive content has a big linear dependence. It seems that the R^2 of these linear models are high except the height of 12 meters. The high variation can also be seen from the Figure 7. The dependences are also naturally negative at all heights. This means that when dry content increases, the extractive content will decrease and on the contrary.

Discussion and conclusions

Studies from the variation of the extractives in the aspen wood after HT-drying cannot be found from the literature. Some recent studies considering chemical changes in softwood can be found e.g. Kotilainen *et al*. (1999) and Alén *et al.* (2002). Studies on a more general level considering effects of high temperatures on chemical composition of wood can be found e.g. Kollmann *et al*. (1967), Shimizu (1972), Hernadi (1977), Hillis (1984), Hsu *et al*. (1989) and Funaoka *et al*. (1990). In all of these studies, the chemical structure of the studied softwoods is found changed so that a degradation of the cellulose chain molecule and oxidation of hydroxyl groups in the anhydroglycosidic units happens. Ko□ķkovį *et al*. (1999) studied chemical interactions in beech during drying processes and found also that beech wood in high temperatures showed partial depolymerization of lignin component as well as the change of the ratio of the crystalline and of the amorphous parts of cellulose.

However, some results concerning total extractive content of aspen can be found. Voipio *et al*. (1992) examined aspen trees small by diameter. They took the samples from 20 % and 80 % heights from the trees and found no significant differences in the extractive contents. According to their estimation, the results may have been caused by the young age of the sample trees. In this study, significant differences after HT-drying were not perceived with different heights either. The results indicate that aspen wood reacts similarly to HT-drying regardless of the position within a tree. The highest extractive content was in 15 meters (2.9 %) but on the other hand the lowest extractive content was in 12 meters (1.8 %). On the height of the stump the extractive content was 2.0 %. In horizontal direction the variation of extractive content was biggest at the heights of 9 and 12 meters, in which the contents decreased rather linearly from the heartwood to the surface. It was not possible to perceive the variation of contents closer to the stump of the tree. The bigger heartwood content of the base may cause this. However, the highest extractive contents were measured quite from the sapwood.

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СОСТАВ ЭКСТРАКТА ДРЕВЕСИНЫ ОСИНЫ *POPULUS TREMULA* ПОСЛЕ ВЫСОКОТЕМПЕРАТУРНОЙ СУШКИ

Т. Кёрки, Я. Вёётёнен

Резюме

Основной целью данного исследования является изучение остаточного состава экстракта древесины осины после высокотемпературной сушки, также исследуя древесину вдоль и поперек ствола дерева. Зависимости определяли методами регрессионного анализа.

Наиболее полным составом экстракта после высокотемпературной сушки обладала древесина полученная рубкой с 15-метровой высоты (2,9 %). На пеневой части бревна состав экстракта составлял в среднем 2,0 %. Вариации состава экстракта в горизонтальном направлении были больше на высоте 9 и 12 метров. В этих точках состав экстракта почти линейно снижается в направлении от сердцевины до поверхности. Более выражена вариация состава экстракта ближе к комлевой части. Причиной этого может быть больший состав сердцевины основания. Однако, наиболее полный состав определяется в лучине.

Ключевые слова: осина, экстракты, высокотемпературная высушка