Properties of domestic birch, aspen and alder and their utilisation in mechanical wood processing

Kotimaisen koivun, haavan ja lepän ominaisuudet ja niiden hyödyntäminen mekaanisessa puuteollisuudessa

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1) Properties of domestic birch and grey alder for mechanical wood processing, and their prediction and control
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2) Mechanical processing and end-use products of domestic birch, aspen and alder
Kotimaisen koivun, haavan ja lepän mekaaninen jalostus, lopputuotteet ja niiden ominaisuudet

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3) Quality of dried wood of cultivated silver birch (*Betula pendula*)
Viljelykoivujen kuivatun puuaineen laatu

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4) Assessment of the quality and industrial value of aspen (*Populus tremula*) for mechanical wood processing
Haavan (Populus tremula) laadun ja jalostusarvon määrittäminen

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Abstract

The purpose of this multidisciplinary research consortium was to study the properties, availability and potential of the wood and timber from Finnish birch (*Betula pendula*, B. *pubescens*), aspen (*Populus tremula*) and grey and common alder (*Alnus incana*, A. *glutinosa*) in mechanical wood processing, both from the view of forestry and industrial processes and end-products.

In subproject 1, a comprehensive literature review on the properties and potential of birch for saw milling and further processing in Finland and a country report from Finland for an inter-nordic preliminary project were published. According to empirical studies mature birch makes the best quality when growing as an admixture in stands dominated by conifers. Recovery of sawable logs per tree and sawn wood per log can be increased by bucking birch into fairly short lengths (ca. 2–4 m). Bucking into small-diameter saw logs in addition to large-diameter logs considerably increases the value of the tree for the forest owner. Basic density and mechanical properties of wood increase from the pith to the surface for both birch species, and decrease slightly from the stump upwards in *B. pendula*; the vertical variation is fairly small in *B. pubescens*. The knot-free stem section as well as about two thirds of the fresh-knot stem section within a birch stem can be reliably identified on the basis of location parameters. For birch from thinnings, defects in the stem form are the most common factors lowering the quality, the percentage of sawable small-sized logs in second-thinning stands of fairly good quality varies between 15–30%. The best saw log recovery is obtained when the stems are harvested and transported as log-sections topped until the minimum sawable diameter followed by the final bucking into saw logs at a separate bucking terminal. There is a high market potential for good-quality alder furniture in Southern Germany. The quality of alder logs in Eastern Finland might be improved by active silviculture. Knottiness is the most common defect in alder lumber, whereas decay is not as common as previous studies indicated. Tools for measuring and grading alder stems and grading and sorting of saw logs were generated and alternative practices were presented for procurement and sawing techniques.

In subproject 2, the mechanical processing properties of birch, aspen and alder wood were clarified. An extensive survey of inquiries and interviews in Finnish enterprises using birch, aspen or alder and an additional interview survey in seven plywood and veneer enterprises were conducted. The results showed that it was difficult to find high quality aspen and alder wood material in Finland. The availability of high quality birch varied a lot depending on the geographical area. For every species, the most processing problems appeared in the first stages, during sawing and drying. Especially successful drying was very important for the further processing properties. Drying was the most important processing sector to be concentrated on in the experimental studies. These included drying experiments of birch and grey alder timber using condense drying and high frequency vacuum (HFV) drying. The material consisted of 59 logs and 25 top blocks of birch and 84 logs of grey alder. As a common feature, the amount of twist increased more in HFV drying, but the colour changes were greater in condense drying. The average length of end checks grew more in HFV drying of green birch timber, whereas the number of checked faces increased more in condense drying. The drying experiments of air-dried timber showed that the average end check length hardly changed even in HFV drying. Cup, bow, spring and differences in moisture content were quite insignificant in both drying methods.

In subproject 3, the main objective was to study the discolouration and deformations of birch sawn timber from plantation forests during conventional and vacuum dryings. Another aim was to study the chemical and anatomical factors, i.e. proanthocyanidin (condensed tannin), as the background for drying defects. Considerable differences in discolouration as well as in proanthocyanidin content of dried wood were observed between different felling seasons and drying methods. The discolouration and deformations of sawn timber from fast-grown planted birches proved to be different from slow-grown natural birches. Furthermore, the lower density of wood of planted birches observed presumably have many effects on the drying behaviour of sawn timber.

In subproject 4, the main aim was to assess the requirements for the quality of aspen saw logs and determine the industrial value of the stems for mechanical wood processing. Different component lengths were used in grading the sawn wood, and it was noted that when shorter lengths of components were used, the proportion of better quality sawn wood increased considerably. Therefore, according to this study, the best yield from aspen timber can be achieved in industry that can manufacture relatively short components of sawn wood. Again, to avoid deformation in sawn timber during drying, the boards to be dried should be relatively narrow, they should be cut into short lengths, and they should be unedged and pith-free.

Tiivistelmä

Tässä monitieteellisessä tutkimuskonsortiossa tutkittiin sekä metsällisistä että teollisten lopputuotteiden ja jalostusprosessien lähtökohdista suomalaisen koivun, haavan ja harmaa- ja tervalepän ominaisuuksia, saatavuutta ja käyttömahdollisuuksia mekaanisessa puunjalostuksessa.

Osahankkeessa 1 julkaistiin kattava kirjallisuustutkimus koivusta sahauksessa ja jatkojalostuksessa ja Suomen maaraportti yhteispohjoismaiseen esitutkimushankkeeseen pohjoismaisen lehtipuun jatkojalostus. Tehtyjen kokeellisten tutkimusten mukaan päätehakkuukoivu saavuttaa parhaan laatunsa havupuuvaltaisissa sekametsissä. Sahauskelpoisten tukkien saantoa rungosta ja sahatavaran saantoa tukista voidaan parantaa katkomalla tukit nykykäytäntöä lyhyemmiksi (2–4 m). Tekemällä rungoista järeiden tukkien lisäksi pieniläpimittaisia tukkeja voidaan rungon kantoraha-arvoa lisätä huomattavasti. Puuaineen tiheys ja mekaaniset ominaisuudet paranevat sekä raudus- että hieskoivulla ytimestä pintaan päin ja alenevat lievästi kannolta ylöspäin rauduksella; korkeusasema ei juuri vaikuta hieksellä. Rungon sisäisesti oksattoman osan sijainti ja suurin osa terveoksaisesta osasta voidaan ennustaa luotettavasti laadituilla ennustemalleilla. Harvennuskoivulla

laadun aleneminen johtui useimmiten runkomuotovioista. Sahauskelpoisten pikkutukkien osuus oli verraten hyvälaatuisissa harvennusleimikoissa 15–30 %. Sahapuukertymä oli paras korjattaessa rungot kokonaisina tukkiosina minimiläpimittaan saakka ja katkomalla sahapölkkypituuksille sahalla tai terminaalissa. Hyvälaatuisille leppähuonekaluille on hyvät markkinanäkymät Etelä-Saksassa. Leppätukkien laatua Itä-Suomessa voitanee parantaa aktiivisella metsänhoidolla. Leppäsahatavaran yleisin vika oli oksaisuus, kun taas laho ei ollut niin yleistä kuin aiemmissa tutkimuksissa on päätelty. Tutkimuksissa laadittiin myös apuvälineitä harmaalepän metsässä tapahtuvaan määrän- ja laadunmääritykseen ja tukkien laadutukseen ja lajitteluun sekä esitettiin vaihtoehtoja tukkien hankinnan ja sahauksen tekniseen toteutukseen.

Osahankkeessa 2 selvitettiin koivun, haavan ja lepän ominaisuuksia ja käyttäytymistä mekaanisessa jalostuksessa. Aluksi tehtiin laaja suomalaisille koivua, haapaa tai leppää käyttäville yrityksille suunnattu postikysely- ja haastattelututkimus ja toinen haastattelututkimus seitsemälle vaneri- ja viiluyritykselle. Tulosten mukaan hyvälaatuista haapaa ja leppää on vaikea löytää Suomesta. Hyvälaatuisen koivun saatavuus vaihtelee huomattavasti alueittain. Kaikilla lehtipuulajeilla mekaanisen jalostuksen ongelmia ilmenee eniten prosessin alkuvaiheissa, sahauksessa ja kuivauksessa. Erityisesti kuivauksen onnistuminen on tärkeää jatkojalostukselle. Kuivaus osoittautui tärkeimmäksi jalostusvaiheeksi, johon keskityttiin kokeellisissa tutkimuksissa. Nämä käsittivät kokeita koivulla ja harmaalepällä lauhdutinkuivausmenetelmällä ja uudella alipaine-suurtaajuusmenetelmällä (HFV-kuivaus). Koemateriaali käsitti 59 koivutukkia ja 25 koivun latvapölkkyä ja 84 leppätukkia. Yhteinen tulos kokeille oli, että kierous lisääntyi enemmän mutta väri muuttui vähemmän HFV-kuivauksessa kuin lauhdutinkuivauksessa. Päätyhalkeamien keskipituus kasvoi enemmän tuoreen koivusahatavaran HFV-kuivauksessa, mutta tyvi- ja latvahaljenneiden lappeiden lukumäärä kasvoi enemmän lauhdutinkuivauksessa. Ulkokuivattua koivutavaraa kuivattaessa päätyhalkeamat eivät keskimäärin pidentyneet paljoa edes HFV-kuivauksessa. Kuperuus, lape- ja syrjävääryys sekä loppukosteuserot olivat merkitykseltään vähäisiä molemmissa kuivausmenetelmissä.

Osahankkeen 3 päätavoite oli tutkia viljelykoivun sahatavaran värin- ja muodonmuutoksia lämminilma- ja alipainekuivauksessa. Lisäksi tutkittiin kuivausvikojen taustalla olevia koivupuun kemiallisia ja anatomisia ominaisuuksia, erityisesti proantosyanidiinin pitoisuuksia (kondensoitunut tanniini). Tutkituista tekijöistä erityisesti koivun kaatovuodenaika mutta myös kasvupaikka, tukkien varastoinnin ajoitus ja kesto ja rungonosa vaikuttavat puuaineen värimuutoksiin. Nopeakasvuisella viljelykoivulla värin- ja muodonmuutokset osoittautuivat kuivauksessa erilaisiksi kuin hidaskasvuisella luonnonkoivulla. Lisäksi viljelykoivun tavallista alhaisemmalla puuaineen tiheydellä lienee monia vaikutuksia sahatavaran kuivauskäyttäytymiseen.

Osahankkeen 4 päätavoite oli määrittää haapasahatukkien laatuvaatimukset ja haaparunkojen jalostusarvo mekaanisessa puunjalostuksessa. Saheiden laadutuksessa käytettiin erilaisia aihiopituuksia; lyhyillä pituuksilla hyvälaatuisen sahatavaran osuus kasvoi huomattavasti. Tutkimuksen mukaan haapasahatavaran saanto on paras silloin, kun voidaan valmistaa suhteellisen lyhyitä saheaihioita. Kuivattavien saheiden tulisi olla suhteellisen kapeita, lyhyitä, särmäämättömiä ja ydinvapaita muodonmuutosvikojen välttämiseksi.

1 Introduction

1.1 Background

The utilisation of broadleaf species in wood product industry in Finland is imperfect. Birch is the most important species, whereas the use of aspen and alder is considerably less. The availability of logs with appropriate quality, insufficient basic knowledge of tree and wood properties and the problems for predicting product quality, bucking and grading and mechanical processing of these species have restricted their use.

Birch is mainly used in plywood industry. Other important product groups are furniture and parquets. Aspen and alder are used in sauna benches and panels, but also more and more in furniture and different kinds of interiors and decorations as well as in various special products. Along with the expanding production of hardwood lumber and their further products, the need for new basic information, as well as solutions for practical problems has grown. Before this project, practically no scientific work was published related to the aforementioned issues in Finland.

1.2 Objectives

The aim of this multi-disciplinary research consortium was to study the properties, availability and potential of the wood and timber from Finnish birch, aspen and alder for the utilization in mechanical wood processing, both from the view of forestry and industrial processes and end-products. Variation of the stem and wood properties in typical mature stands, their dependence on factors of the growing conditions and the performance of wood procurement and primary processing and the possibilities to predict and control the properties from the point of view of mechanical processing were considered. Mechanical processing properties were clarified by inquiry and interview surveys and experimental sawing and drying studies. In addition, drying of planted silver birch as well as the quality of birch from thinnings were studied.

2 Results and conclusions

Subproject 1 covered studies on: 1) physical and mechanical properties of wood, as well as stand, tree, log and sawn wood characteristics and quality, and timber recovery and bucking principles of Finnish silver birch (*Betula pendula*) and white birch (*B. pubescens*) originated from naturally born, mature stands; 2) harvesting strategies, timber recovery, as well as saw log and sawn wood properties and quality of birch from second-thinning stands; 3) availability, properties and suitability of grey alder for mechanical processing, as well as markets for grey alder products. Along with these studies, an extensive literature research was performed on birch for saw milling and further processing in Finland.

For ***mature birch***, the main results were: 1) birch makes the best quality (size, knottiness, stem form) when growing in stands dominated by conifers; 2) considering the raw material usage (recovery of sawable logs/tree) and sawing process (recovery of sawn wood/log), it would be useful to buck birch saw logs into fairly short lengths (ca. 2–4 m); 3) bucking both small-diameter and large-diameter saw logs considerably increases the value of the tree for the forest owner, compared to bucking large-diameter saw logs and pulpwood only, or veneer logs and pulpwood; 4) basic density and, therefore, mechanical properties increase from the pith to the surface of the stem for both birch species, and decrease slightly from the stump upwards in *B. pendula*, whereas, in *B. pubescens*, the vertical variation is small; 5) the knot-free stem section and the majority of the fresh-knot stem section within the birch stem, can be reliably identified on the basis of location parameters; the rest of the fresh-knot stem section could not be reliably separated from the dead-knot section.

For ***birch from thinning stands***, the main results were: 1) defects in the stem form are the most common factors lowering the quality of the thinning removal; 2) the percentage of sawable small-sized logs from the removal in second-thinning stands of fairly good quality varies between 15–30%, the remaining 70–86% being pulpwood; 3) the best saw log recovery is obtained when the stems are harvested and transported as log-sections topped until the minimum sawable diameter, followed by the final bucking into saw logs at a separate bucking terminal; 4) on average, as much as 4.4 m^3 logs were needed for 1 m^3 of fully edged lumber, and 3.3 m^3 for 1 m^3 if all utilizable lumber was counted.

For ***grey alder*** the principle findings were: 1) Eastern-Finnish SMEs are interested in processing alder logs and producing furniture as well as joinery products of alder; 2) there is a high market potential for good-quality alder furniture in Southern Germany; 3) the quality of alder logs in Eastern Finland might be improved by active silviculture; 4) knottiness is the most common defect in alder lumber, whereas decay is not as common as supposed.

In **subproject 2**, an extensive survey consisting of 82 inquiries and 81 interviews in Finnish enterprises using birch, aspen or alder as raw material was conducted first. It is difficult to find high quality aspen and alder wood material in Finland. The availability of high quality birch varied a lot depending on the geographical area. Most of the problems in processing appeared in sawing, planing and especially in drying. Different kinds of distortions, colour changes and drying checks were common in all species. The moisture content of aspen, in particular, varied a lot before and after drying, even in different parts of the same piece, making further processing difficult.

Another interview survey was aimed at seven Finnish plywood and veneer enterprises using birch, aspen or alder as raw material. Birch was used most, whereas the use of aspen and black alder was slight and grey alder was not used at all. Knots, sweep of logs, disturbance of grain and rot were the most harmful material properties of birch and black alder, complicating especially turning. Incorrect bucking of logs was also a typical problem. Rot, knots and checks were the most typical defects in aspen wood. For aspen veneers, drying times are longer in the same thickness and gluing is more complicated compared with birch veneers.

For all species, the most problems appeared in the first stages of the process, during sawing and drying. Especially successful drying was important for further processing properties. The experimental studies included drying experiments of birch and grey alder timber using condense drying and high frequency vacuum (HFV) drying. The material consisted of 59 logs and 25 top blocks of birch and 84 logs of grey alder. Birch logs and blocks were simple cut to 25-mm sawn timber, grey alder logs to 19 mm. Half of the sawn unedged birch timber was kiln-dried immediately and half was air-dried for six months before kiln drying. All of the sawn unedged grey alder timber was air-dried for six months before kiln drying.

In drying of green birch timber, the number of checked faces increased more, but the average length of end checks and the amount of twist increased less in condense drying than in HFV drying. The amounts of cup, bow and spring were rather small and nearly the same in both drying methods. Visually observable colour changes increased clearly in condense drying, whereas in HFV drying the colour remained nearly the same. Differences in moisture content between the surface and the inner part and between the top, middle and butt of the pieces were quite small after both HFV and condense drying.

In condense and HFV drying of air-dried birch timber the average length of end checks increased equally at the top end. Twist increased clearly more in HFV drying but cup, bow and spring were nearly the same in both drying methods. Colour changes were greater in condense drying than in HFV drying. Differences in moisture content between the surface and the inner part were small after both HFV drying and condense drying. Distortions of birch planks (25 mm x 48 mm x 1100 mm) from air-dried pieces remained nearly the same in HFV drying, excluding twist which increased most. The number and the average length of end checks did not increase at all. The colour of the planks hardly changed; some planks seemed to be even lighter after drying than before drying.

In condense drying of air-dried grey alder timber the average length of end checks stayed at the same level before and after drying. In HFV drying the average length of end checks even decreased a little. Again twist increased clearly more in HFV drying. The colours of the pieces changed more in condense drying than in HFV drying.

In **subproject 3**, growing site, felling season, timing of storage period of logs and location of wood in the trunk were the factors hypothesised to have effects on the discolouration and deformations. In addition, the chemical and anatomical factors presumed to be as the background for drying defects (i.e. proanthocyanidin), were studied.

Discolouration of sawn timber was the greatest in summer during conventional drying and in winter during vacuum drying. The general lightness was clearly lower in vacuum-dried than in conventionally dried sawn timber. After conventional drying, the colour of the surface layer was always lighter and varied more between different felling seasons than the colour of the inner wood, but, after vacuum drying, the colour of the surface layer was always darker. Physiological changes of trees between seasons and during temperatures below freezing point were supposed to change the drying properties of birch wood, which causes differences in the discolouration between seasons. Furthermore, the mechanism of the process of discolouration in the two drying methods proved to be different.

The lightest conventionally dried wood from winter-felled trees contained more proanthocyanidin (condensed tannin) than the wood from summer-felled trees. The proanthocyanidin content was also clearly lower in dark-coloured vacuum-dried wood than in conventionally dried wood. The radial location of wood in the trunk affected the colour more than the longitudinal location, the colour being darker and more red near the pith than near the trunk surface. In anatomical examination, both the diameter of vessels and thickness of cell walls were found to be the greatest in summer-felled wood and the smallest in winter-felled wood. Deformations of sawn timber during drying were relatively large compared to the earlier experiences with natural birches. Also the deformations were found to vary seasonally, being the largest in summer. The density of wood was considerably lower compared to the density values presented in literature for natural birches. It decreased remarkably in the radial direction from the wood near the bark to the wood near the pith, and, to some extent, in longitudinal direction from the base of the butt log to the top of the butt log.

All the factors studied here contribute to the discolouration of birch wood. The drying properties of sawn timber from fast-grown plantation forests proved to be different from those of slow-grown natural birches as the extent of the discolouration and deformations was found to be different. Furthermore, the lower density of wood of planted birches observed presumably have many effects on the drying behaviour of sawn timber. Therefore, further research focused on the adjustment of drying schedules for birch sawn timber of different origin and of different felling time is needed.

In **subproject 4**, the main aim of the study was to assess the requirements for the quality of aspen saw logs and determine the industrial value of the stems for mechanical wood processing. The three subaims were the following: 1) define the quality of aspen sawn timber, 2) study the variation in the physical properties of aspen wood within and between aspen stems and 3) study the drying quality of aspen timber based on test dryings.

In general, aspen logs have knots from the base to the top. The knot-free section at the base of butt logs is usually short, although, all in all, butt logs have fewer knots than other kind of logs have. The difference between a dry-knot section and a fresh-knot section is more obvious than, for example, in grey alder. According to this study, knottiness in aspen is comparable to that in birch. When the grading of Keinänen and Tahvanainen was tested, none of the logs could be classified into grade A or B. The main reason for this was the excessive number of knots, the second reason for grade reduction was rot. When sawn wood was graded, the same two main reasons remained valid for grade reduction, i.e. knots and rot. When the number of logs between different grades and the amount of sawn wood within a given grade were compared, it was found that the grade distributions were fairly comparable to each other. The criteria for better quality grades might still be too strict, because such a small number of logs and sawn wood met the criteria of grade A, B or C, and most of the logs and pieces of sawn wood were classified as rejected. Therefore the criteria for the different grades should be re-evaluated. Different component lengths were used in grading the sawn wood, and it was noted that when shorter lengths of components were used, the proportion of better quality sawn wood increased considerably. Therefore, the best yield from aspen timber can be achieved in industry that can manufacture relatively short components of sawn wood.

The results showed that wood density of European aspen is the highest in the living crown. At lower heights (up to 12 metres) wood density is also higher just beneath the bark rather than in the pith. The volume shrinkage in aspen wood is the largest in the middle of the cross-section pith-surface and the smallest close to the pith. Longitudinal shrinkage grew slightly upwards from the height of 3 metres, radial wood shrinkage was the smallest at stump height and at the height of 15 metres and tangential shrinkage was the smallest at the height of 15 metres and it remained quite steady within tree.

Increasing the width of a sawn piece of aspen had both positive and negative effects on drying quality. However, according to the models, for wider boards there are more negative effects on drying quality than for narrower ones. An increase in the length of a sawn piece also increased the length of cracks. Pith-free sawing is strongly recommended, because when a sawn piece contains pith, the cracking is very obvious. After drying, both positive and negative effects on quality were seen in both edged and unedged sawn pieces. The positive effects of drying unedged are still undoubtedly greater, while bow and crook deformities can be mostly prevented by drying the boards unedged. After drying, there are more crook deformities in rapidly grown rather than in slowly grown timber. Thickness of board (19/32 mm) had no effect on drying quality. In summary, to avoid deformities in aspen sawn timber, the boards to be dried should be relatively narrow, they should be cut into short lengths, and they should be unedged and pith-free.

4 a) Capabilities generated

The extensive literature study of subproject 1 reports the background, potential and preconditions for increasing the use of birch in mechanical industries, and the knowledge gained on tree and wood properties and their variation in birch and grey alder showed the potential and indicated improvements in practices for characterising, selecting, sorting, bucking and grading raw materials. All-time first results were gained for birch from thinnings for sawing and furniture; these studies continue in Eastern Finland in 2001–02, in collaboration with four enterprises. In collaboration with subproject 4, one doctoral thesis was completed on grey alder.

The scientific publications constitute another doctoral thesis on mature birch.

The extensive surveys of subproject 2 aimed at enterprises offer comprehensive information concerning the use, processing problems and products of birch, aspen and alder. Problems in kiln drying are very common and they strongly affect the later parts of the production process. The survey gave a good basis to plan the experimental part. Due to the restricted economical and time resources and the large variety of species, the experimental part was simultaneously a preliminary study for a more comprehensive project which gained funding from Tekes and 7 enterprises. This project started in spring 2001 and will be carried out during the years 2001–2002.

The studies of subproject 2 will form the basis for a doctoral thesis, together with the new project.

The knowledge of the general variation in the appearance of discolouration between different felling seasons in planted birch material as well as of the chemical and physiological reasons for the discolouration increased through the results from subproject 3.

The scientific results will be published and they will constitute one doctoral thesis.

According to subproject 4, the best yield from aspen timber can be achieved in industry that can manufacture relatively short components of sawn wood. The main results of the subproject are published in five different peer-reviewed scientific articles.

In collaboration with subproject 1, one doctoral thesis was completed on grey alder.

b) Utilisation of results

The results increasing the knowledge of hardwood resources (volume, distribution, quality and its control) and their sawing, drying and further processing are directly utilised for the development of practices in wood procurement and processing by the enterprises as well as the forest owner association and researchers in the management group of the consortium.

The main results of the entire consortium were published in June 2001 on the web sites of Wood Focus Ltd/ Puuinfo Ltd (www.puuoske.com). This report was also mailed to 100–200 enterprises using birch, aspen or alder as their raw material and a number of related R&D organisations. The survey reports of subproject 2 were mailed to all enterprises involved. A number of articles for professional journals were written and lectures and posters were presented in different professional and scientific workshops. The Centre of Expertise for Wood Products (1999–2006) will disseminate the results through its workshops and discussion forums to forestry, forest industry and manufacturers of woodworking machinery.

5 Publications

Articles in international scientific journals with referee practice

Heräjärvi, H. 2000. Technical properties of mature birch (*Betula pendula* and *B. pubescens*) for saw milling in Finland. Silva Fennica. Accepted.

Heräjärvi, H. & Verkasalo, E. 2001. The effect of bucking method on timber grade distribution of mature Betula pendula and pubescens stems in Finland. Forest Products Journal. Submitted.

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Kärki, T. 2001. Drying quality modelling of European aspen (*Populus tremula*) timber. Holz als Roh- und Werkstoff. In print.

Kärki, T. 2001. Variation of wood density and shrinkage in European aspen (*Populus tremula*). Holz als Roh- und Werkstoff 59(1/2): 79-84.

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Kärki, T. & Vainikainen, V. 2001. Determining the quality of aspen (*Populus tremula*) logs for mechanical wood processing in Finland. Forest Products Journal. Submitted.

Luostarinen, K. & Luostarinen, J. 2000. Discolouration and deformations of birch parquet boards during conventional drying. Wood Science and Technology. Accepted.

Luostarinen, K., Möttönen V., Asikainen A. & Luostarinen, J. 2000. Effect of environmental factors and wood location in trunk on birch (*Betula pendula*) wood discolouration during drying. Holzforschung. Submitted.

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Möttönen, V. & Luostarinen, K. 2001. Discolouration of sawn timber of silver birch (*Betula pendula*) from plantation forests during conventional kiln drying and vacuum drying. Holzforscung. Submitted.

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6 Cooperation

Advisory group

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Riitta Keiski, University of Oulu,
Faculty of Technology
Matti Niemi, Niemen tehtaat Ltd.
Esko Ovaskainen, Oy Karelia Parketti Ltd.
Leena Paavilainen, Wood Wisdom
Olli Saikku, Mahogany Ltd.
Juhani Saimovaara, Puuseppämestarit ry.

Matti Saramäki, Federation of North Carelian Forest Owners’ Associations
Sauli Valkonen, Finnish Forest Research Institute, Vantaa Research Centre

Other domestic users of results include, among others, enterprises in mechanical processing of birch, aspen and alder (in addition to those represented in the advisory group) and organisations promoting private forestry, forestry syndicates, trade and promotion organisations of the industry, and regional development organisations.

Collaboration in the inter-Nordic project Further processing of Nordic hardwoods 1998–99 (SNS). Other international contacts include Lövträinstitutet (Sweden), FORINTEK Canada Corporation, Eastern Division, Quebec City, and the University of Aberdeen, UK.

The drying experiments of subproject 2 were carried out in condense and HFV drying kilns of Lahti Polytechnic, Faculty of Technology and those of subproject 3 for vacuum drying at the Mikkeli Institute of Environmental Technology.

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