# Effects of Provenance, Radial Location of Wood and Drying Schedule on Colour of Dried Siberian Larch (*Larix sibirica*) Timber

**KATRI LUOSTARINEN*[1] AND SAMULI HEIKKONEN[2, 3]**
[1]*School of Forest Sciences, University of Eastern Finland, Box 111, FI-80101 Joensuu*
*katri.luostarinen@uef.fi, phone +358-13-251 2717*
[2]*YTI Research Centre, Jääkärinkatu 10 A, FI-50100 Mikkeli*
[3]*Current address: Metsäliitto Cooperative, Finnforest, Plywood, P.O. Box 42 (Vaneritehtaankatu 1), FI-44201 Suolahti*

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*Abstract*

Siberian larch (*Larix sibirica* Ledeb.) timber is a good raw material, particularly for the mechanical wood industry, but drying it without any decrease in value is difficult and slow. The purpose of this research was to determine if radial location or drying schedule affect the colour of conventionally dried larch wood coming from two different provenances (Finland and Siberia). The basic density, final moisture content and width of annual rings differed between provenances and were taken into account as covariates. A total of five drying tests with three different schedules were performed, with reflectance spectra being measured from the inner parts of dried timber. The effect of drying schedule on the colour was minor. However, radial location affected the colour more clearly. The middle and inner heartwood were darker and redder than the wood located near the pith, particularly in the Siberian timber, while the wood located around the pith was reddest in the Finnish timber. In addition, the colour correlated with density regarding the Siberian, but not the Finnish timber, with the colour of the timbers of different provenances visibly differing. Thus provenances should be separated when drying larch wood to attain uniform colour.

**Key words**: annual ring width, basic density, conventional drying, L*C*h -colour coordinates, moisture content

## Introduction

Timber of Siberian larch (*Larix sibirica* Ledeb.) is a good raw material for the mechanical wood industry. Larch wood is highly suitable for interior use because it contains smaller amounts of volatile organic compounds than e.g. Scots pine wood (*Pinus sylvestris* L.) (Viitanen et al. 2001). Another important issue, for wood species used for valuable carpentry products meant for interiors, is its colour and general appearance. The most appreciated part of larch is its reddish, commonly even dark reddish (Lyck and Bergstedt 2007), heartwood which constitutes up to 85% of the wood in old trees (Use of larch ...1971). The red tone is lacking from the sapwood, where the colour is duller. Another factor affecting the appearance of larch wood is its strong patterning of annual rings, which is mainly due to the large density differences between earlywood and latewood (Hakkila and Winter 1973). In fact, the very clear colour differences between earlywood and latewood partly cover noticeable average colour differences between timber pieces that are apparent to the naked eye.

The success of drying determines, to a great extent, the quality of the dried timber for the intended use, as well as possibly influencing the colour. Usually the higher the dry temperature is in drying, the more the wood darkens. The effect of drying on the wood colour has been studied for many wood species, particularly for hardwoods (e.g. McMillen 1976, Charrier et al. 1992, Luostarinen et al. 2002, Möttönen and Luostarinen 2004) but also for softwoods like pines (*Pinus radiata* D. Don, *P. sylvestris* L.), spruce (*Picea abies* (L.) Karst.) (Wiberg 1996, Kreber and Haslett 1997, Repola et al. 2001), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and firs (*Abies* ssp.) (Kreber and Byrne 1994). In most of the cited studies, concerning softwoods, the colour of the surface of timber pieces, with or without planing off a few millimetres, has been studied, because the water soluble compounds of wood have been observed to move towards the surface of the timber piece, affecting its colour (Boutelje 1990, Theander et al. 1993, Terziev 1995). In the case of Siberian larch, the wood from the core to the surface of a timber piece has been observed to be uniform or slightly darker near the surface after very thin planing (Heikkonen et al. 2007). Furthermore, the radial location of sawn timber may affect the colour because of differences in density (Kärkkäinen 1978) and in the width of annual rings in the radial direction.

The purpose of this research was to examine the colour of conventionally dried Siberian larch timber from the perspective of the carpentry industry, in which there is a need to plane the surfaces thoroughly away and split the original timber pieces into smaller dimensions. Thus the inner colour of timber pieces was compared after drying with three different drying schedules. Provenance and radial location of the timber were taken into account when the effects of different schedules on the colour were determined.

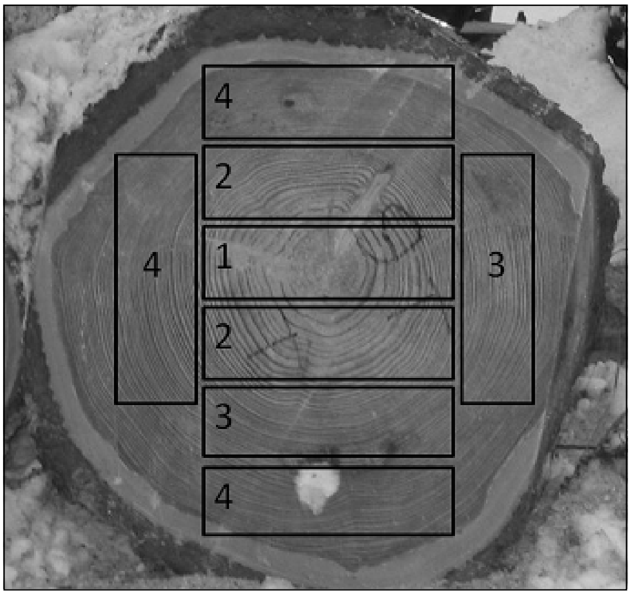


**Figure 1.** Sawing pattern, X-log, used in this study. Numbers refer to the grading of planks according to their radial location in the trunk. The scale used was 1) planks containing the pith, 2) planks from the innermost heartwood, 3) planks from the middle of the heartwood, and 4) planks containing both heartwood and sapwood, referred in text as outer heartwood, because the reflectance spectra were always measured from the heartwood

## Materials and methods

### *Wood material*

For this study the Siberian larch timber came from two different provenances; Finland and Siberia. The climates of the provenances differ from each other according to mean winter temperature, which is -15 – -20°C in Siberia at the region of Ust Ilimsk (58°15’ N, 102°75’ E; north-west of Krasnoyarsk) from where the used timber came, and -5– -10°C in Finland at Punkaharju region (61°81’ N, 29°32’ E; south of Joensuu), and according to annual rainfall, ca. 460 mm at Krasnoyarsk region and over 600 mm at Joensuu region. Mean summer temperature is 15–20°C at both regions (World climate 2008).

The used timbers were harvested in December (Finland) and in October – December (Siberia) 2005, when the timbers were frozen. The Finnish timber, total of 17 trees, came from the plantations of the Finnish Forest Research Institute, Punkaharju, Eastern Finland, from a forest that was planted in 1924 with four-year-old seedlings. The Siberian-grown Siberian larch came from Ust Ilimsk from a natural forest. As the Siberian timber was purchased (from Pariwood Oy, Parikkala, Finland) as ready sawn, the number as well as the age of the original Siberian trees are unknown. However, the width of annual growth and curve of annual rings suggested that the trees were quite old, most probably older than the Finnish trees.

The 4.5 m long logs of the trees of the Finnish origin were sawn in Punkaharju using the X-log method (Figure 1) with a small portable circular saw, while the Siberian timber was sawn in Siberia. Both origins were sawn into planks of 50 mm x 150 mm. In connection with sawing, the distance of the planks from the pith was determined for the Finnish timber (Figure 1). However, for the Siberian timber the distance was determined from the curve of annual rings, and existence of the pith, sapwood and bark. The used radial classification of the planks refers to the cambial age of the wood, and the wood from the innermost location containing the pith consisted mainly of juvenile wood, while the class 2, inner heartwood, consisted partly of juvenile and partly of mature wood. The two outermost locations included only mature wood. Total of 53 planks from both provenances were used for this study.

Samples of 20 mm length for basic density (kg/m$^3$) were taken from the distance of 30-120 cm from the upper end of the original planks when cutting them to a suitable length, 1.2 m, for the kiln used in this study. The distance of the samples from the upper end of the original planks varied, because they were divided for several drying test each requiring timber of different length, and because knots and other irregularities in wood were not included into the samples to avoid their effect on basic density. The effect of the different sampling height, 3.3 – 4.2 m, on the wood properties is most probably small (e.g. Kärkkäinen 2007). The exact dimensions of the samples were measured with a digital Mitutoyo sliding gauge and they were weighed immediately after cutting from green planks with a Precisa XB 4200C scales. The samples were then dried at a temperature of 103 ± 2°C, according to the standard EN 13183-1 (2002), in a Memmert oven, and weighed, after which the basic density was calculated (Table 1). The average annual growth (mm/a) (Table 1) was determined by calculating the number of whole annual rings in a given distance, and then dividing the distance by the number of annual rings. Final moisture content (MC) (Table 1) was measured from 20 mm long samples taken from the middle of the dried planks. The samples were dried at a temperature of 103 ± 2°C and weighed, and the MC (%, $g_{water}$/$g_{dry\ wood}$; g=gramme) was calculated. The means and standard errors of the mean for the basic density, width of the annual rings and final MC are presented by drying lot, as well as by radial location, since these factors were used as covariates in the used General Linear Model (GLM) procedures.

***Drying***

All the timber, except the lot which was dried first (60°C), was kept in a freezer room (-20°C) until moved to room conditions to be prepared for the drying process about 24 h beforehand. Even though the storage times in freezer varied from 4 weeks to ca. 4 months, no significant decrease in the MC just before starting the drying processes was observed (results not shown). Both the Siberian and the Finnish grown timber were includ-

**Table 1.** Basic densities, annual growths, final moisture contents and numbers of used samples by provenances, radial locations (drying lots combined) and drying lots (radial locations combined), which were named according to used dry temperature and material included if different between lots dried in the same temperature. SE – standard error of the mean, * – significant difference between provenances, S+F – lot contained timber from both provenance, S/F – lot contained timber of one provenance (S – Siberia, F – Finland)

| Property | Radial location | Finland Mean±SE | Siberia Mean±SE | Drying lot | Finland Mean±SE | Siberia Mean±SE |
|---|---|---|---|---|---|---|
| Basic density | Outer heartwood | 533.3±8.4 | 525.5±9.4 | 50°C | 515.7±11.1 | 513.1±8.4 |
| (kg/m$^3$) | Middle heartwood | 509.6±9.9 | 517.6±12.5 | 60°C* | 482.1±14.6 | 522.1±12.8 |
| | Inner heartwood* | 461.0±6.3 | 523.5±16.3 | 70-80°C S+F | 484.4±18.5 | 518.1±19.0 |
| | Pith included* | 411.1±10.0 | 511.6±11.8 | 70-80°C S/F | 486.3±13.5 | 528.3±14.5 |
| Annual growth | Outer heartwood* | 2.01±0.13 | 0.98±0.04 | 50°C* | 2.95±0.19 | 1.03±0.09 |
| (mm/a) | Middle heartwood* | 2.98±0.16 | 1.18±0.10 | 60°C* | 3.36±0.39 | 1.30±0.10 |
| | Inner heartwood* | 4.50±0.29 | 1.51±0.18 | 70-80°C S+F* | 3.23±0.45 | 1.16±0.12 |
| | Pith included* | 5.33±0.33 | 1.32±0.09 | 70-80°C S/F* | 3.54±0.42 | 1.39±0.16 |
| Final moisture content | Outer heartwood | 8.6±0.43 | 11.18±1.25 | 50°C | 9.2±0.33 | 12.4±1.72 |
| (%) | Middle heartwood | 8.1±0.41 | 10.56±0.95 | 60°C* | 8.9±0.45 | 13.0±0.85 |
| | Inner heartwood | 7.1±0.77 | 9.9±1.49 | 70-80°C S+F | 7.9±0.48 | 10.4±1.20 |
| | Pith included | 6.0±0.38 | 9.3±0.69 | 70-80°C S/F | 5.9±0.21 | 7.3±0.51 |
| Number of planks | Outer heartwood | 18 | 19 | 50°C | 11 | 11 |
| | Middle heartwood | 19 | 16 | 60°C | 13 | 13 |
| | Inner heartwood | 8 | 9 | 70-80°C S+F | 13 | 11 |
| | Pith included | 8 | 9 | 70-80°C S/F | 16 | 18 |

**Table 2.** Programmed drying schedules. T - temperature, EMC - equilibrium moisture content, DF - drying force (DF=MC/EMC). S+F - lot contained timber from both provenances, S/F - lot contained timber of one provenance (S - Siberia, F - Finland)

| | | Lots | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Lot 50°C | Lot 60°C | 50°C & 60°C | | Lots 70-80°C S+F, S & F | | |
| Stage of process | | T | | EMC | DF | T | EMC | DF |
| Heating up | | 50 | 60 | 18 | | 70 | 18 | |
| Drying, | > 70% | 50 | 60 | | 2.6 | 70 | | 2.6 |
| | 60-70% | 50 | 60 | | 2.6 | 70 | | 2.6 |
| | 50-60% | 50 | 60 | | 2.6 | 70 | | 2.6 |
| | 40-50% | 50 | 60 | | 2.6 | 70 | | 2.6 |
| | 30-40% | 50 | 60 | | 2.4 | 70 | | 2.6 |
| | 25-30% | 50 | 60 | | 2.3 | 75 | | 2.7 |
| | 20-25% | 50 | 60 | | 2.3 | 80 | | 2.7 |
| | 15-20% | 50 | 60 | | 2.6 | 80 | | 2.7 |
| | 10-15% | 50 | 60 | | 2.7 | 80 | | 3 |
| | <10% | 50 | 60 | | 1.4 | 80 | | 3 |
| Conditioning | | 50 | 50 | 9.8 | | 65 | 8.6 | |
| Cooling down | | 40 | 40 | 9.8 | | 40 | 8 | |
| Stopping of ventilation, °C | | 40 | 40 | | | 40 | | |
| Targets | | Lot 50°C | Lot 60°C | | | Lot 70-80°C S+F | Lot 70-80°C S | Lot 70-80°C F |
| Target final MC, % | | 10 | 10 | | | 10 | 10 | 8 |
| Target MC gradient, % | | 1 | 1 | | | 1 | 0.1 | 0.1 |

ed in three of the processes, and one test was carried out for the Finnish and one for the Siberian timber alone. The schedule for the lots including only Siberian or Finnish timber was the same as the hottest one used for the lot consisting of both timbers (Table 2). The drying lots are referred to according to the temperatures used and in the case of the three lots dried with the same schedule, also as the provenance of the timber included in the lot (F – Finland and/or S – Siberia).

In the laboratory size conventional kiln B 9400 COMP used, manufactured by Brunner Hildebrand GmbH, the drying processes are controlled by the wood MC. In this study the process control was done according to the MC of the Finnish timber when both timbers were dried in the same process. Drying schedules for the kiln are made by determining the drying temperature and the drying force (DF; DF=MC/EMC; EMC=equilibrium moisture content) for ten MC intervals in the drying phase, while the climates for heating, conditioning and cooling down are determined by temperature and EMC. Water spraying is used in the heating phase to moisten the surface of the timber. In addition, target final MC and MC gradient must be determined.

### *Measurements of reflectance spectra*

To measure the reflectance spectra of the inner wood of the planks, each plank was split radially and the inner surface was planed. The spectra were measured with a portable spectrophotometer MINOLTA CM 2002, using a 2° standard observer and standard illuminant $D_{65}$. Furthermore, the spectra were measured from three points (diameter 11 mm) of each plank, the average of the three measurements being the result for the plank. The spectra were always measured from the heartwood, avoiding knots and other defects. Additionally, the whole annual rings, i.e. both the earlywood and latewood, were included in the measurements.

L*C*h coordinates were determined from the measured reflectance spectra (e.g. Precise colour ... 1994). The L* coordinate, lightness, is scaled so that zero corresponds to black and one hundred to white. C*, chroma, presents the saturation of colour, and it takes values between 0-60, 0 being dull/grey and 60 being very vivid colour. Hue angle, $h_{ab}$, represents the hue: the values are degrees, 0° being red, 90° yellow, 180° green and 270° blue. The difference between hues of two measurements, ÄH*, was calculated (Eq. 1) between provenances by both drying lots and radial locations (e.g. Precise colour ... 1994):

$$\Delta H^* = \sqrt{(\Delta E^*_{ab})^2 - (\Delta L^*)^2 - (\Delta C^*)^2} \quad (1)$$

where $\Delta E^*_{ab}$ is colour difference, calculated as (Eq. 2)

$$\Delta E^*_{ab} = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (2)$$

where ΔL*, Δa*, Δb* and ΔC* represent the differences in L*, a*, b* and C* values, respectively, between two measurements. In the case of larch wood, a* and b* get positive values and thus represent red and yellow tones, respectively, but the values of a* and b* are not presented, because they are in close connection with hue angle and chroma.

### *Statistics*

Colour coordinates were compared according to drying schedules and radial locations using the General Linear Model (GLM) of SPSS software, keeping the Finnish and Siberian timbers separate. In addition, the provenances were compared using GLM according to radial locations and drying lots. Basic density, width of annual rings, and final MC were used as covariates because there were differences in them between provenances, as well as radial locations and drying lots, and therefore may have affected the colour; this was verified by partial correlations of annual ring width, basic density and final MC with colour coordinates (SPSS software). In these correlations, the effects of two of the three basic properties (basic density, final MC, annual ring width) were eliminated when calculating the correlation between colour coordinates and one of them.

## Results

Colour coordinates of the Finnish timber did not correlate with any of the three basic properties (basic density, final MC, annual ring width) taken into account. However, in the Siberian timber density and MC correlated with some colour coordinates. The denser the wood, the darker it was and the higher the chroma and thus the more vivid the colour, while MC affected the hue angle: the higher the MC, the smaller the hue angle, i.e. the hue became redder (Table 3). However, the hue angle values of 72°- 78° measured

**Table 3.** Observed statistically significant partial correlations between colour coordinates, and basic density (BD), annual growth (AG) and final moisture content (MC). Significant correlations were observed only for the timber of the Siberian origin. r – correlation coefficient, p – significance ($p<0.05$ were considered as statistically significant)

| Comparison | | Controlling factors | Siberia | |
|---|---|---|---|---|
| | | | r | p |
| Lightness, L* | BD | MC, AG | -0.459 | 0.002 |
| Chroma, C* | BD | MC, AG | 0.473 | 0.002 |
| Hue angle, $h_{ab}$ | MC | BD, AG | -0.387 | 0.011 |

in this study, represent orange, almost yellow, tones. Instead, the width of annual rings did not correlate with any of the colour coordinates.

The covariates used in the GLM procedures made some clear differences between the averages statistically insignificant, on the one hand, and some small differences significant, on the other hand. Some significant differences in colour coordinates were observed between the radial locations of the wood (Table 4a), as well as between the drying lots (Table 4b). In the Finnish timber the differences in lightness between radial locations were minor (Figure 2a, Table 4a). However, in the Siberian timber, the wood located in the middle or inner parts of the heartwood was slightly darker than the outer heartwood and the wood in the vicinity of the pith (Figure 2a, Table 4a). Furthermore, the chroma shows a decreasing trend from outer to the innermost heartwood particularly in the Finnish timber (Figure 2b, Table 4a), and the hue angles of the Finnish and Siberian timber had radially opposite trends: the Finnish wood was the most yellow in the middle and outer locations of the heartwood, while the wood from the vicinity of the pith was the most yellow in the Siberian timber (Figure 2c). However, statistically significant differences were rare (Table 4a). In addition, the Finnish timber was redder, according to the hue angle, than the Siberian timber in each radial location while the differences in the other colour coordinates between the provenances were not significant (Figure 2, Table 5a).

Some statistically significant differences in colour coordinates were observed between the drying lots (Figure 3, Table 4b). The Siberian timber was lighter when dried at 50°C or 60°C than at 70-80°C (Figure 3a, Table 4b). However, in the Finnish timber no statistical differences in the lightness nor the chroma were observed, while the chroma in the Siberian timber increased significantly when the drying temperature was raised (Figure 3b, Table 4b). In the Siberian timber the quite small difference in the hue angle between 60°C and 70-80°C S+F was significant, that of the former being higher and thus indicating a slightly more yellow hue (Figure 3c, Table 4b). In the Finnish timber two statistical differences in the hue angle were observed between the lots: the hue angle increased when the temperature was raised from 60°C to 70-80°C (S+F),

**Table 4.** Observed statistically significant differences in colour coordinates between a) radial locations and b) drying temperatures, calculated with GLM procedure using basic density, annual growth and moisture content as covariates. p – significance of the comparison (p<0.05 were considered as statistically significant). S+F – lot contained timber from both provenances, S/F – lot contained timber of one provenance (S – Siberia, F – Finland)

a)

| Property | Comparison | | Finland | | Siberia | |
|---|---|---|---|---|---|---|
| | | | F | *p* | F | *p* |
| Lightness, L* | Outer heartwood | Inner heartwood | | | 5.060 | 0.039 |
| “ | Middle heartwood | Inner heartwood | 6.474 | 0.020 | | |
| “ | Middle heartwood | Pith included | | | 6.729 | 0.018 |
| “ | Inner heartwood | Pith included | | | 5.034 | 0.049 |
| Chroma, C* | Outer heartwood | Pith included | 10.441 | 0.004 | | |
| Hue angle, $h_{ab}$ | Middle heartwood | Inner heartwood | 9.001 | 0.007 | | |
| “ | Middle heartwood | Pith included | | | 8.894 | 0.008 |

b)

| Property | Comparison | | Finland | | Siberia | |
|---|---|---|---|---|---|---|
| | | | F | *p* | F | *p* |
| Lightness, L* | 50°C | 70-80°C S+F | | | 5.318 | 0.035 |
| “ | 60°C | 70-80°C S+F | | | 22.108 | 0.000 |
| “ | 60°C | 70-80°C S | | | 7.364 | 0.014 |
| Chroma, C* | 50°C | 70-80°C S | | | 6.271 | 0.022 |
| “ | 60°C | 70-80°C S | | | 6.670 | 0.019 |
| Hue angle, $h_{ab}$ | 60°C | 70-80°C S+F | 4.730 | 0.043 | 7.651 | 0.014 |
| “ | 70-80°C S+F | 70-80°C F | 10.141 | 0.004 | | |

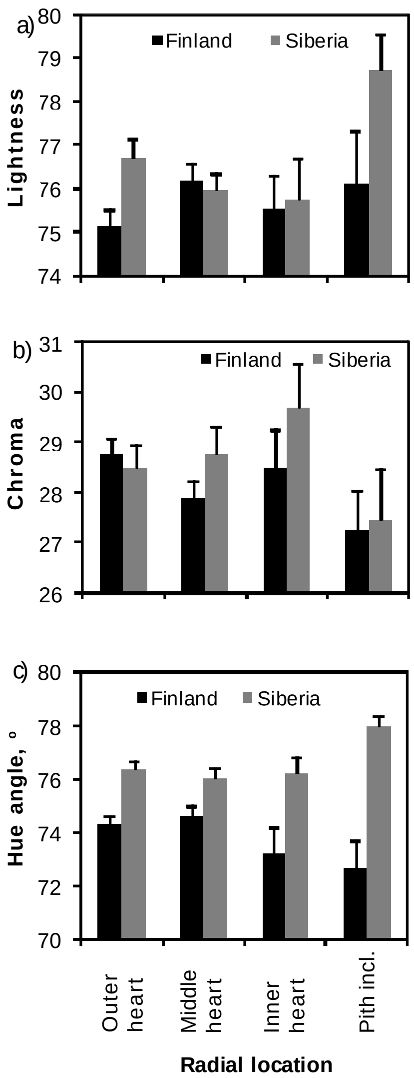


**Figure 2.** a) Lightness, b) chroma, and c) hue angle of the inner wood of the Finnish and Siberian planks according to radial location

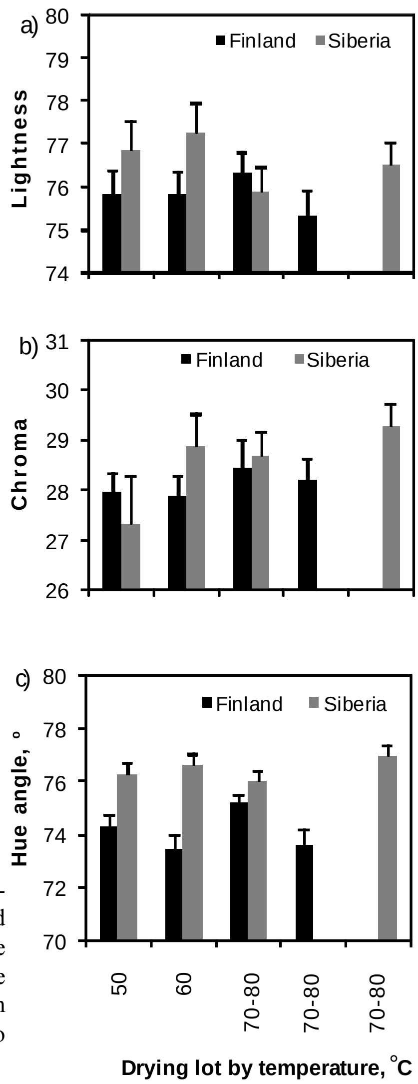


**Figure 3.** a) Lightness, b) chroma, and c) hue angle of the inner wood of the Finnish and Siberian planks according to drying lot

and decreased again when the Finnish timber was dried alone at 70-80°C.

The Finnish timber was slightly, but significantly, lighter than the Siberian timber when provenances were dried together at 70-80°C, other differences in lightness between provenances being opposite but insignificant (Table 5b). No differences in the chroma between the Finnish and Siberian timbers were observed, but the hue angle was generally higher in the Siberian than in the Finnish timber within a drying lot. Furthermore, it was higher in the Siberian timber dried alone than in the Finnish timber dried alone (Table 5b). Observed ΔH* values between timbers of different provenance according to both radial location and drying lot were quite small (Table 6), but a slightly redder and darker tones in the Finnish than in the Siberian timber were observed, with it being possible to see most of the differences with the naked eye.

**Table 5.** Differences in colour coordinates between the Finnish and Siberian timbers according to a) radial locations of timber and b) drying lots, calculated with GLM procedure using basic density, annual growth and moisture content as covariates. p – significance of the comparison ($p<0.05$ were considered as statistically significant). S+F – lot contained timber from both provenances, S/F – lot contained timber of one provenance (S – Siberia, F – Finland)

a)

| Property | Radial location | F | *p* |
|---|---|---|---|
| Hue angle, $h_{ab}$ | Outer heartwood | 8.993 | 0.006 |
| Hue angle, $h_{ab}$ | Middle heartwood | 16.114 | 0.000 |
| Hue angle, $h_{ab}$ | Inner heartwood | 6.051 | 0.036 |

b)

| Property | Drying lot | F | *p* |
|---|---|---|---|
| Lightness, L* | 70-80°C S+F | 5.912 | 0.026 |
| Hue angle, $h_{ab}$ | 60°C | 5.910 | 0.028 |
| Hue angle, $h_{ab}$ | 70-80°C S+F | 16.140 | 0.001 |
| Hue angle, $h_{ab}$ | 70-80°C S/F | 6.203 | 0.020 |

**Table 6.** Hue (ΔH*ab) differences between Finnish and Siberian timber according to radial locations and drying lots. S+F – Siberian and Finnish timber were included in the same drying lot, S/F – Siberian and Finnish timber were dried in different lots

| Radial location | $\Delta H^*_{ab}$ | Drying lot | $\Delta H^*_{ab}$ |
|---|---|---|---|
| Outer heartwood | 1.02 | 50°C | 0.89 |
| Middle heartwood | 0.74 | 60°C | 1.58 |
| Inner heartwood | 1.54 | 70-80°C S+F | 0.42 |
| Pith included | 2.51 | 70-80°C S/F | 1.72 |

## Discussion and conclusions

Differences in the wood materials, i.e. basic density and MC, affected the colour of the Siberian, but not the Finnish grown *Larix sibirica*, timber. Annual ring width did not correlate with the colour coordinates, which was expected, because both earlywood and latewood width increase when the ring width of mature wood increases (Zhu et al. 1998). This stabilises the effect of the wood types, over several annual rings, on the colour in the mature wood. The lower the MC was, the higher the hue angle, i.e. the more yellow the tone. Regarding the wood of Scots pine and Norway spruce the hue angle was also found to increase with decreasing MC during drying (Wiberg 1996). In practice it looks likely that hue differences caused by MC differences even out by the time when the MC differences equalise between timber pieces. Furthermore, the denser the Siberian grown wood, the darker it was, with the colour becoming simultaneously more saturated. The heartwood contains a higher concentration of extractives, compared to sapwood, (e.g. Viitanen et al. 2001, Gierlinger et al. 2004a,b, Venäläinen et al. 2006), that have an effect on colour through increasing density as such, but also because some of the extractives are coloured. However, no effect of density on hue angle was observed, which suggests that the amounts of the red-coloured phenolics (Gierlinger et al. 2004a) did not differ between timbers of different density. Density also affects other properties such as final MC and MC gradient of dried larch timber (Luostarinen et al. 2010, Luostarinen and Heikkonen 2010), which emphasises its importance when larch timber of comprehensively good quality is produced.

Differences in wood colour were observed regarding the radial locations. The juvenile wood of the Siberian timber with quite narrow rings was clearly lighter in colour than the mature wood. However, wide annual rings did not make the Finnish juvenile wood lighter than its narrower-ringed mature wood, even though in the juvenile wood the width of latewood is constant, the width of the lighter earlywood increasing when the width of annual ring increases (Zhu et al. 1998). The reason may be that the concentration of coloured extractives might have been quite high in the Finnish timber, because good growth rate increases the produced extractive amount, as observed in European larch (*L. decidua* Mill.) (Gierlinger and Wimmer 2004) and in Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) (Taylor et al. 2003). Thus the growing site may particularly affect the colour of the earlywood, because it usually contains more extractives than the latewood (Côté et al. 1966), but the amount of extractives may also be increased in the latewood. However, extractive content of the wood decreases more the older the wood becomes because of increasing acidity (Cōté and Timell 1967, Cōté et al. 1967), which may, for its part, make the colour lighter towards the pith. It is most likely that the Siberian grown natural trees were clearly older than the Finnish grown 85-year-old trees which suggests that acidity, of particularly the juvenile wood, had increased more in the Siberian than in the Finnish trees. Correspondingly, the highest concentration of extractives has been found in the heartwood located near the heartwood-sapwood boundary (Cōté et al. 1966, Cōté and Timell 1967, Gierlinger and Wimmer 2004), which is in accordance with the findings of this study: the middle and outermost heartwood were the darkest. Thus the radial location of wood may affect the wood colour by wood age (acidity, extractive concentration), but ring width does not have much effect.

Relative humidity of air (RH) was kept quite constant in the hottest lots with a slight lowering at the end of the processes while in the two lots with lower temperature, RH was raised when MC was 20-40%. This, together with temperature, might have caused the observed weak tendency that lower temperatures produced lighter wood than the highest temperature. For birch it has been observed that timber should be dried to an MC of about 15-20% before making the schedule more severe to minimise the darkening (Luostarinen and Luostarinen 2001). However, the colour of different provenances differed from each other in this respect between schedules, which was seen particularly in the lots in which timber of one origin was dried alone. The provenance also affected the colour of the wood of Scots pine (Grekin 2006). The reasons for the colour differences between the provenances are probably partly genetic, but the differences in climate and soil properties count, as well, as they affect the growth rate (Antonova and Stasova 1997, Kirdyanov et al. 2003, 2006), and thus extractive content (Taylor et al. 2003, Gierlinger and Wimmer 2004). This suggests that the best results concerning wood colour would be achieved through each timber provenance having its own drying schedule.

Thus, as a conclusion, drying schedule had quite a small effect on larch wood colour, which, however, was different for the two provenances of timber. Provenance, as well as radial location, visibly affected the colour of dried larch wood. Furthermore, provenance affected the basic density of wood and the effect of basic density on the colour. Additionally, wood age, taken into account as radial location of wood in this study, is a marked factor affecting the colour. Thus to achieve larch timber of uniform colour and thus suitable for valuable carpentry products, timbers of different provenances should be dried separately.

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# ВЛИЯНИЕ ГЕОГРАФИЧЕСКОГО ПРОИСХОЖДЕНИЯ, РАСПОЛОЖЕНИЯ ГОДОВЫХ КОЛЕЦ И РЕЖИМА СУШКИ НА ЦВЕТ СУХОЙ ДРЕВЕСИНЫ ЛИСТВЕННИЦЫ СИБИРСКОЙ (*LARIX SIBIRICA*)

**К. Луостаринен и С. Хейкконен**

*Резюме*

Древесина лиственницы сибирской (*Larix sibirica* Ledeb.) является качественным сырьем, в особенности, для деревообрабатывающей промышленности. Однако она сложно подается сушке без потери качества, и это занимает много времени. Целью данного исследования было выяснить, влияет ли расположение годовых колец или режим сушки на цвет высушенной традиционным способом лиственницы из двух разных географических точек (Финляндия и Сибирь). Учитывалась плотность абсолютно сухой древесины, конечная влажность и ширина годовых колец по географическому происхождению сырья. Всего было проведено три опыта сушки при разных режимах, измерялось диффузное отражение внутренней части сухой древесины. Влияние режима сушки на цвет оказалось минимальным. Однако расположение годовых колец оказывало более четкое влияние на цвет. Наружные и средние кольца были темнее и краснее расположенных вблизи сердцевины, особенно у древесины сибирского происхождения, в то время как у финляндской древесины тенденции окраски были обратными. Кроме того, у сибирской древесины, в отличие от финляндской, цвет зависел от плотности, и между древесиной разного происхождения наблюдалось серьезное отличие. Таким образом, для достижения однородного цвета древесина разного происхождения при сушке должна разделяться.

**Ключевые слова**: ширина годовых колец, плотность сухой древесины, традиционная сушка, цветовые координаты CIELCh, влажность