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ORIGINAL ARTICLE

Central European wood species: characterization using old knowledge

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Abstract A characterization of wood species was made by analyzing almost 9000 museum objects which still carry the handwriting of former craftsmen. In total 48 different wood species could be distinguished, including 17 shrub species. In the next step, every part of museum inventory with a given wood species was connected to its required wood properties in use and technological demands. In this way, every wood species was characterized by its former utilization. It was found, that many wood species which are not in use anymore were highly appreciated. Many shrubs were used because of their high density, which provides also hardness and good resistance against abrasion. Some fruit-bearing trees would be worth utilizing in a more sophisticated and specialized way as they are used today. Most species are highly specialized and show individual wood properties, which becomes clear by focusing on how they were utilized.

Keywords Wood species · Wood properties · Characterization · Historical wood utilization

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Introduction

In Austria, the choice of commercially available native wooden species includes approximately 24 species [1]—considerably less than what is indigenous in the forests. It is common knowledge that, based on differing material properties, different wood species like for example oak (*Quercus* spp.) and popular (*Populus* spp.) cannot be used in the same field of application. Some properties are so much diverse that these two wood species have to be handled like two different materials. Therefore, we have to be aware of the whole range of properties that can be covered by all available wood species, to exhaust the full potential of wooden materials.

Today, more than 60 % of the Austrian forest area is covered by Norway spruce (*Picea abies*) [1]. However, this silvicultural strategy is stretched to its limit. Therefore, the cultivation of a higher variety of wooden species would also give a chance to a more sustainable forestry [2].

Many valuable wood species are not in use any more, which led to a decline on possibilities in wood utilization. The aim of the present study is to outline the huge potential of the wide range of wood properties covered by today rarely used wood species, to meet the demands of modern wood utilization.

Wood is increasingly replaced by other materials and the number of wood species used for everyday products is reduced compared to earlier times. Radkau [3] criticizes that the weakness of one wood species is compensated by coping and adhering wood to engineered wood products, rather than being sublimated by another wood species.

Not even 100 years ago, most of the daily used items were made of wood. Iron was a sign of wealth and not affordable by everyone [4]. Wood had to meet all requirements, in particular those of people living in the

countryside. Different parts of an object had to deal with different loads. This led to high complexity concerning the choice of the wood species.

At the beginning of the 20th century, the folklorist Josef Blau investigated a bohemian household and counted 27 wood species. He emphasized that all species were chosen according to their specific wood properties [4]. This indicates that knowledge about the proper utilization of wood and the selection of wood species was sorted out at some point in history—knowledge that might be usable today.

In modern literature [e.g., 5] some wooden species are not even mentioned, especially woody shrubs. Old literature [e.g., 6] often does not cover all species and all applications, because a lot of knowledge was passed on from one generation to the next orally and was never written in books. Therefore, it is necessary to analyse wooden objects to understand past wood utilization.

Theory

To characterize wooden species, we can harvest and measure them according to modern mechanical testing procedures, or we use the experience of our ancestors, who gained their knowledge over hundreds of years by trial and error. In this investigation, the second way was chosen and wood species were characterized due to its former utilization. This approach is founded by the following arguments:

1. It is the only possibility to find out which species have been in use for which purposes.
2. It is usually not only one single property, but rather the combination of some properties as well as technological demands which is decisive for selecting a wooden species.
3. Some properties cannot easily be measured, such as lubricity, blistering due to working or all haptic properties.

Nevertheless, a currently ongoing testing procedure of rarely used wood species as well as a comprehensive literature analysis will give complementary information to the findings of this study to present an extensive characterization of native wood species.

To figure out which species have been used, one can either search literature or take the direct way by analyzing old wooden objects as they are still exposed. Usually they are still in the original state and show the handwriting of former craftsmen. In this study, both opportunities were taken.

Today, some rarely used wood species are appreciated because of their color, as they were in the past for furniture and gallantry items. But, color was not a selection criterion for most other commodity items. Anyway, the main source of information was the inventory of museums (commodity items), which is usually not lacquered or oiled and therefore discolored by UV radiation, carbon black or dirt and therefore not suitable for further analyses. By being aware of all properties from all available wooden species, for instance, new products could be developed. This article will not provide any concrete ideas of new utilization, but this study should initiate a thinking process regarding future wood utilization from a different point of view.

The goal was to describe the combination of utilization, technical demands and resulting necessary properties of the wood species which were in former use to give a "backwards characterization".

Materials and methods

Historic inventory of five Austrian museums has been analyzed. One museum is located in Gutenstein in Lower Austria, dealing with forestry and forestry byproducts. They show all kinds of working tools and working aids connected with work carried out in the forest (www.waldbauernmuseum.at). Two museums are located in Carinthia, in the very southern part of Austria. One of them is a museum of folk culture, presenting the way of living in the alpine region (www.museum-spittal.com). The other one is the first Carinthian museum of handicrafts (www.handwerksmuseum.info). Another two museums are located in Styria. One of them is located in Stainz, dealing with agriculture, showing all kinds of items needed for plant and animal breeding (www.museum-joanneum.at/en/landwirtschaftsmuseum/agriculture-museum). The other one is the Austrian Open Air Museum in Stübing, close to Graz, where the largest number of objects was analyzed. They exhibit almost 100 appointed farmhouses from all over Austria (www.stuebing.at).

Sampling implied the identification of the wood species used. Determination was done by analyzing anatomical features [5, 7, 8]. Some species were detectable by just using a magnifying glass to enlarge the wood structure. For others a transmitted light microscope had to be used. Most diffused porous species and today rarely used species had to be sampled by sectioning by hand [5]. Very thin pieces of all anatomical directions were taken from the objects. These samples, having 20–50 µm thickness were placed under a transmitting light microscope, to make features on microscopic level visible.

In some cases, just the genus can be determined, not the species itself (*Acer* spp., *Quercus* spp., *Tilia* spp., *Populus* spp., *Salix* spp., and *Ulmus* spp.). In two cases not even the differentiation of the genera is completely sure, this is for pear (*Pyrus communis*) and apple (*Malus domestica*) [8]. To handle these problems, the different species of one genus

were not separately analyzed and the genera *Pyrus* and *Malus* were grouped together. For the genus *Sorbus* spp. the differentiation of the wood species (European mountain ash (*Sorbus aucuparia*), Wild service tree (*Sorbus torminalis*), Common whitebeam (*Sorbus aria*) and True service tree (*Sorbus domestica*) is difficult, but it was tried to distinguish the species using the description of Greguss [7].

For evaluation, a database was created where the identified wood species are linked to:

(A) the object that was sampled,
(B) the region where the object was found and
(C) the wood properties which were decisive for selecting the given wood species.

To make evaluation clearer, the objects had to be grouped first (also object parts and object details were put into groups), e.g., a hammer, an axe and a hatched are grouped to tool handles. The different loads, technological as well as special demands of each single piece were discussed with handicraft men and museum staff knowing the objects in use. Based on these analyses up to six wood properties were assigned by the authors. Below a further discussed expressive subset will be described as they were understood in the context of the study (compare also [9]).

Mechanical properties

(high) Strength: this capacity implies the ability of wood to carry loads and includes bending strength, compressive strength, tensile strength, torsional strength and shear strength.

(high) Impact strength: the capacity of wood to absorb impact energy without breaking. It is essential in wain production.

(high) Vibration damping: vibration damping is required for skis or the handles of striking tools.

(high) Hardness: hardness indicates the capacity of wood not to be engraved by another wooden piece or another material—it is required, e.g., for planes.

(high) Abrasion resistance: the resistance of a wooden surface against mechanical wear. For instance the plate of a wooden table needs a high resistance against abrasion.

Wood structure and wood chemistry related properties

(high) Dimensional stability: good dimensional stability is related to low shrinkage as well as to keep proportions stable. It is important for instance in vessel production so that the ring does not get loose and makes the product leaking.

(good) Fissility: Fissility implies easy splitting of wood and the possibility to gain a plain surface through splitting, as it is needed to produce boards or staves.

(high) Durability: the resistance against biological degradation. It is required for all outdoor applications.

(low) Sliding friction: the resistance against the relative motion of two surfaces in contact. For instance a wheel bearing or a spindle need low sliding friction.

Anti-bacterial behavior: the ability of wood to prevent bacterial growth, which is important for butter production or generally if there is contact to food.

Next, it was analyzed, how often one wood property was connected to a specific wood species. For this purpose, the required wood properties were assigned to every object part. The counts of one property in connection with one species were summed up and divided by the total frequency of the given species. The resulting index displays the percentage of objects showing the individual properties within each wood species and is further on referred as property index. The property index is therefore a measure of the relative importance of the wood property for a specific species and can vary between values of 0 and 1 (with 1 meaning 100 % assignments of a property for a certain species). The index is illustrated as a bubble chart where only wood species appearing more than ten times are shown.

Additionally, radarcharts for the described species (see below) were drawn. These figures are based on the same data set, but present the properties in another way.

Sampling in the museum was expanded by a search of historical literature. On the one hand, books dealing with the descriptions of different wood species were analyzed focusing on today rarely used species. From this category 41 books published between 1798 and 2009 were analyzed. On the other hand, folkloristic literature was searched to extract which wood species had been mentioned there. In this category 91 citations published between 1888 and 2012 were included. The characterization of the wood species in the books was compared to the characterization made after evaluating the wood species used in the museum objects.

Results and discussion

In this investigation, 4335 objects and thereof 8985 object parts have been sampled. In total 48 different wood species could be identified. Figure 1 shows a bar chart with all species put in order, starting with most frequently identified ones, which was spruce (*Picea abies*) followed by beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*) and birch

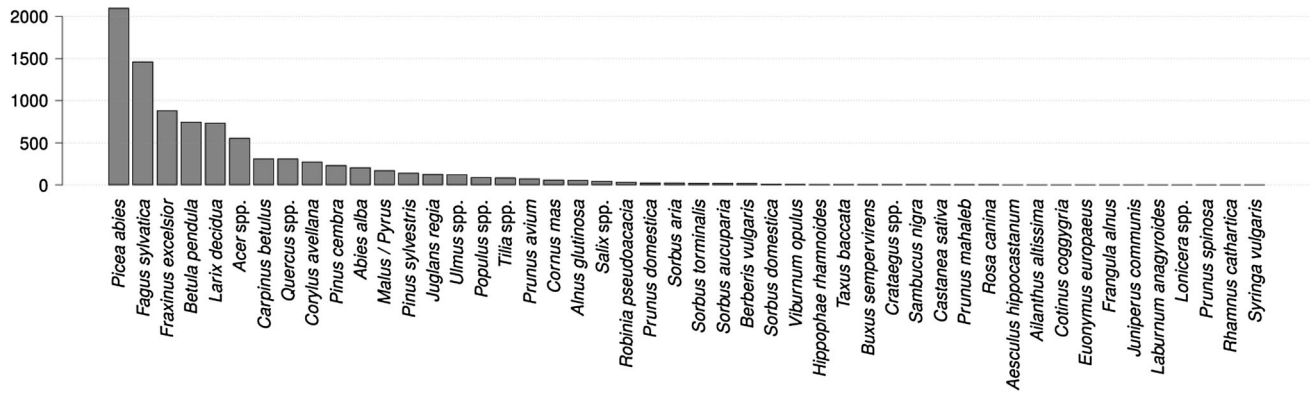

Fig. 1 The *bar chart* shows the frequency (total number of objects) of the identified wood species

(*Betula pendula*). Within these 48 wooden species, 17 species can be classified as shrub. The most frequently used shrubs were hazelnut (*Corylus avellana*), cornelian cherry (*Cornus mas*) and barberry (*Berberis vulgaris*). Furthermore there are ten different fruit-bearing trees included, such as pear (*Pyrus communis*) or apple (*Malus domestica*), cherry (*Prunus avium*), plum (*Prunus domestica*), rocky cherry (*Prunus mahaleb*) walnut (*Juglans regia*) and four different species of genus *Sorbus* spp. Apple and pear were anatomically not distinguished and grouped together.

Figure 2 gives an overview of the calculated property index with bigger bubbles for higher index values to no bubble for an index value of zero. As stated above the property index is a measure of relative importance of a wood property for a given species, therefore the bubble helps to compare the importance of a property with other properties of a certain species as well as with the same property of other species. In addition the bubble sizes can give an idea of the overall importance of a certain property for the objects investigated as more important properties have generally bigger bubbles at all or most of the species while lesser important ones have generally smaller or no bubbles (see "high durability"). The theoretically biggest bubble size of an index value of 1, respectively, 100 % is shown on the right side of the figure.

To go more into the details, important properties will be analyzed. Easy processing was necessary for most applications and is generally the big advantage of the raw-material wood; therefore it was not further analyzed. Other important properties were resistance against abrasion and dimensional stability. Both are properties which today would be satisfied using metals. In former times, however, only few people were able to afford any other material than wood. Consequently, they chose wood species which were able to fulfill these requirements in the best possible way. To provide resistance against abrasion apple (*Malus domestica*), pear (*Pyrus communis*), barberry (*Berberis vulgaris*), cherry (*Prunus avium*), plum (*Prunus domestica*), hornbeam (*Carpinus betulus*), maple (*Acer* spp.), robinia (*Robinia pseudoaccacia*), *Sorbus* spp. or walnut (*Juglans regia*) was chosen first. To guarantee dimensional stability cornelian cherry (*Cornus mas*), hazelnut (*Corylus avellana*), poplar (*Populus* spp.) and oak (*Quercus* spp.) were selected; species such as spruce (*Picea abies*), fir

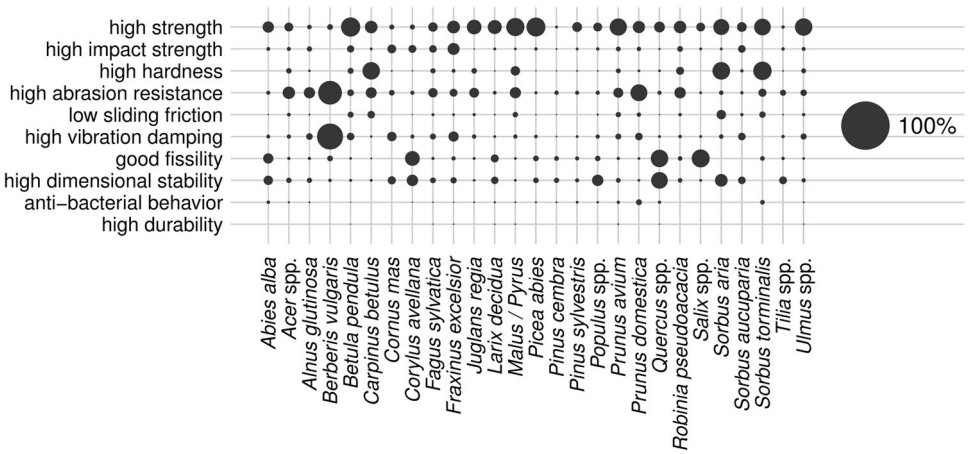

Fig. 2 Bubble chart of assigned wood properties per species (for wood species with more than 10 counts) showing the calculated wood property index, with *bigger bubbles* for higher index values to *no bubble* for an index value of zero

(*Abies alba*) and larch (*Larix decidua*) were used for vessel production and had to be dimensionally stable enough for this application. For high strength multiple species were chosen, for objects requiring high surface hardness hornbeam (*Carpinus betulus*), wild service tree (*Sorbus torminalis*), common whitebeam (*Sorbus aria*) was taken, and for good fissility silver fir (*Abies alba*), oak (*Quercus* spp.), hazelnut (*Corylus avellana*) and willow (*Salix* spp.) were used.

Shrubs

In Austria, 2.5 % of the utilized woodland area is covered with shrubs which is more than by fir (2.3 %) or oak (2 %) [10]. Nevertheless, the wood of shrubs is not commercially used today, although the wood properties of many shrubs would be worth utilizing. If all shrubs are grouped together, they rank in the eighth position of the most utilized species in former times (Fig. 1)—more than 5 % of all objects were made of wood coming from shrubs. Figure 3 lists the dry wood density of all identified wood species in the project (Niklasova S., diploma thesis at BOKU Vienna 2009) and [5]. It is noticeable that many shrubs have high density values between 0.8 and 1 g/cm^3. This can be compared with hornbeam (*Carpinus betulus*), being the commercially used species with the highest density value of 0.74 g/cm^3 and oak (*Quercus* spp.), having 0.64 g/cm^3

The high density is one of the properties that make shrubs valuable, but with wood density other properties such as strength follow [9].

Focusing on shrubs wood properties being outstanding according to the constructed database, high resistance against abrasion and a good vibration damping has to be mentioned and can easily be seen in Fig. 4.

Three shrubs were chosen to be described in detail. These are cornelian cherry, barberry and hazelnut:

Cornelian cherry (*Cornus mas*) is one of the wood species having the highest density (Fig. 3). It was selected, if high impact strength, good vibration damping and good dimensional stability were required (Fig. 4). It was used for tool handles, for rungs of ladders, for objects in textile industry, e.g., as weavers shuttle or for striking tools such as mallet or threshing flail. In the analyzed folkloristic literature it is mentioned only once for the wooden tooth of a harrow [11]. In old literature dealing with wood species it was highly praised (e.g., Moeller, [12]). It is described to be hardly fissile, hard and fibrillar [13]. To the above mentioned range of application, teeth of combs [14] and clock mechanisms [15] can be added from the literature.

Barberry (*Berberis vulgaris*) was used for its high resistance against abrasion and good vibration damping (Fig. 2). Most rake teeth were made of barberry and also folklorist literature mentions the wood to be best suitable for this application [16]. Interestingly, the literature

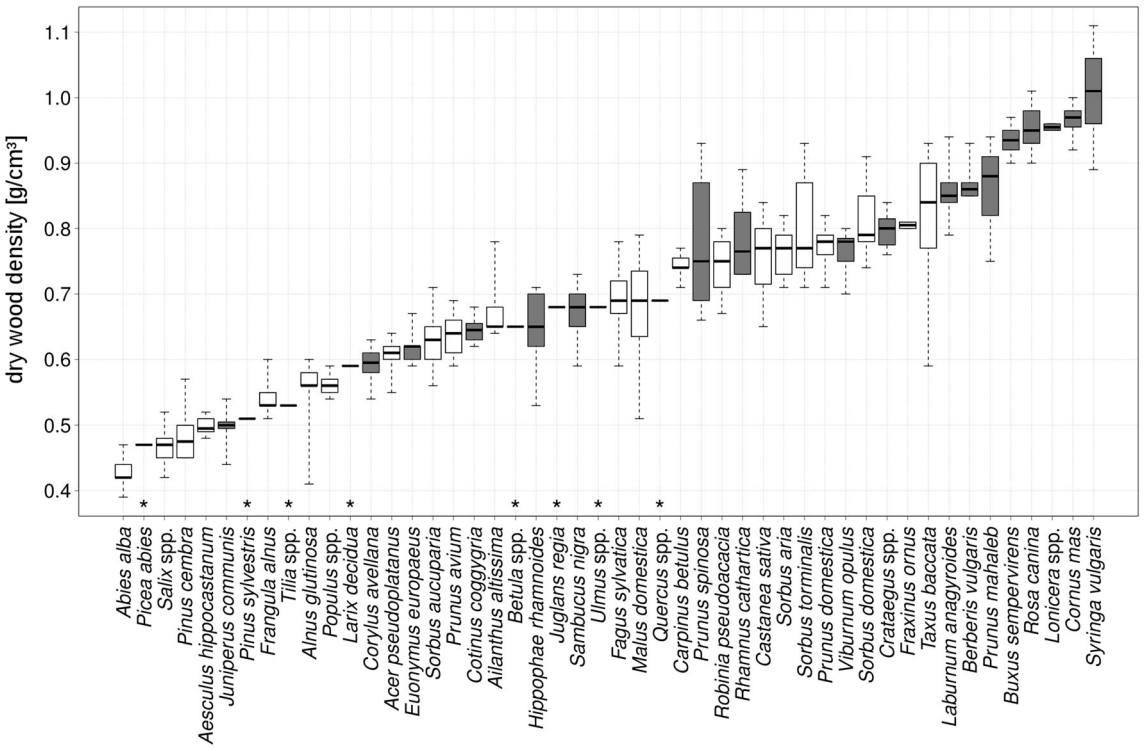

Fig. 3 Dry wood density values of all analyzed wood species. Shrubs are marked *gray* [11]. Density values for species marked with "asterisk" taken from [5]

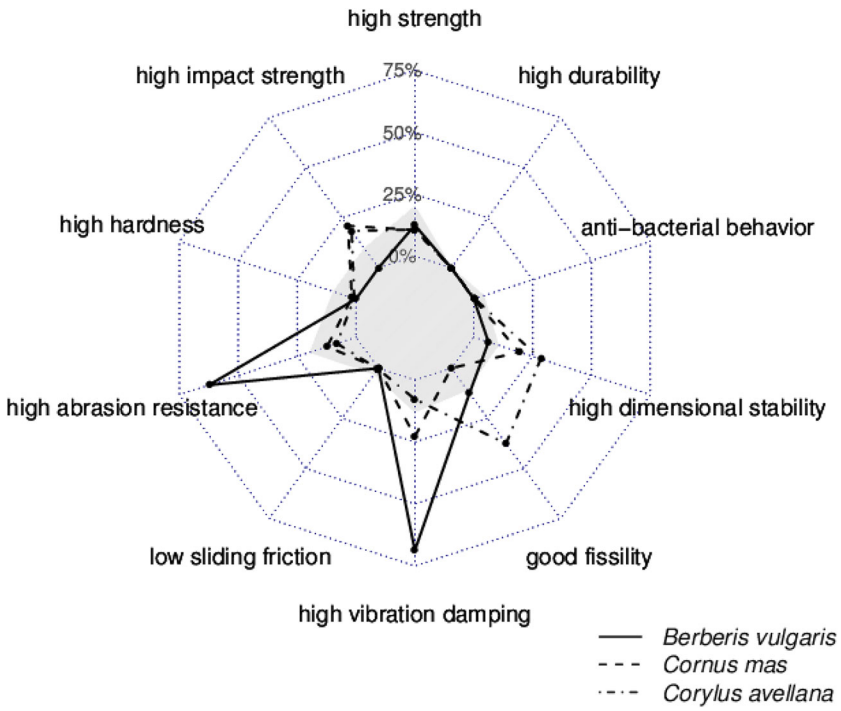

Fig. 4 Radarchart for three selected shrub species showing the wood property index. The *gray area* is indicating the mean values of all 48 species

describing wood properties does not mention rake teeth made of barberry at all, but recommends using it for inlays, due to its nice yellow color [14].

Hazelnut (*Corylus avellana*) sticks out of the group of shrubs. It was the most utilized shrub, ranking on its own in eighth place of the most utilized species (Fig. 1). In contrast to most other shrubs, hazelnut was not used because of its high density. It was used because of its high flexibility (not shown) and good fissility (Fig. 4). Therefore, it was used for barrel hoops and for all basket-works (more than 50 % of all wattle was made of hazelnut). Furthermore it was utilized for tool handles, walking sticks and skiing sticks. The literature also mentions hazel for the same field of application [17] or [18].

Currently rarely used tree species

It is not only that the utilization of shrubs almost disappeared, but also the utilization of some valuable tree species is widely reduced. These are generally fruit-bearing trees as cherry trees, apple trees, pear trees and trees from the genus *Sorbus* spp. which cannot be harvested and processed in a fast industrial way. If all fruit-bearing trees are grouped together, they rank in the sixth place of the former most utilized species. Figure 5 shows the superior properties of these selected species: strength, hardness and abrasion resistance.

Apple and pear (*Malus domestica* and *Pyrus communis*) are anatomically hard to distinguish, therefore they are discussed together. The wood of those two species is still appreciated for furniture making and veneer production. Nevertheless, the wood could be challenged much more. In former times apple and pear were often utilized because of their combination of high resistance against abrasion, hardness, strength and comparable low sliding friction (Fig. 5). It was used for planes, spindles, cogwheels, shafts, axis and rolls. There are also other parameters like lubricity, which is one of the properties difficult to measure. They can be evaluated by analyzing historical objects representing the result of a long-term empirical process. Pear and apple were conspicuously often used for friction bearing where the named property is of great importance. Folkloristic literature mentions rolls for prayers beads [19], pounders [20], plows [21], oil presses [22] and windmills [21].

Cherry (*Prunus avium*) and plum (*Prunus domestica*) have similar properties and are discussed together. They were appreciated because of their high resistance against abrasion, high strength, good vibration damping and comparable low sliding friction (Fig. 5). They were often used for small parts of machines such as axis, cogwheels and spokes. Furthermore it was utilized for outlets of vessels and furniture as table toppers. In folkloristic literature, cherry was mentioned to be used additionally for furniture as beds and chairs [15] as well as for rakes [20], mortars [23] and skids [24]. Plum was found in literature as spinning wheels [21], wooden nails of wains [25] and presses [26].

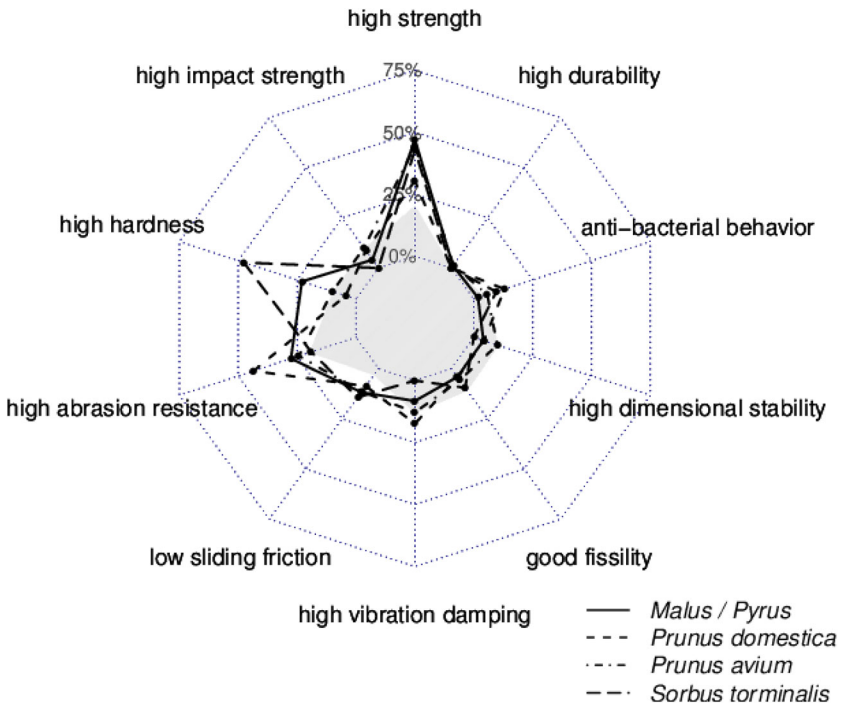

Fig. 5 Radarchart for four selected rarely used tree species showing the wood property index. The *gray area* is indicating the mean values of all 48 species

The genus *Sorbus* spp. includes European mountain ash (*Sorbus aucuparia*), Wild service tree (*Sorbus torminalis*), Common whitebeam (*Sorbus aria*) and True service tree (*Sorbus domestica*). Today it seems as if their fruits are more popular and more utilized than their wood. They were in some application used like apple and pear according to their properties such as resistance against abrasion, good in food contact (anti-bacterial), good sliding friction and high strength and hardness. They were used for planes, for spindles or beams of presses or for wood in water contact such as printing plates or wash boards. Furthermore the wood was appreciated in food contact such as outlets of vessels or bakers cutlery and in textile industry for weavers shuttle or looms. In literature it is also highly appreciated, even in modern publications [27]. The literature mentions in addition musical instruments [28], measuring instruments [29] and rolls of machines [14].

Generalist and specialists

European beech (*Fagus sylvatica*) was by far the most frequently used hardwood species (Fig. 1). 20 % of all analyzed object parts were made of beech. The wide distribution was one reason, the rather good wooden properties the other. Beech is the only wood species which possesses all the analyzed properties attributes—to a greater or lesser extent. The wood was found in all categories and groups, but was never seen as a specialist. Figure 6 shows that the index values of beech mostly follow the mean values of all 48 species. In contrast, the other species had at least one property with superior index values.

Birch (*Betula pendula*), on the contrary, was highly specialized. Almost 40 % of all spindles were made of birch wood—regardless if the spindle was needed in big sizes for mills or in very small sizes for spinning wheels. Furthermore shoe makers nails or wooden spikes were hardly made out of any other wood species. Nowadays, birch is generally an underestimated wood species, not at least because forest management fosters birch at some times and frowns on it at other times [30] or [31]. Nevertheless, birch was very appreciated in former times. Almost 10 % of all object parts were made of birch (Fig. 1). It is especially mentioned in all areas of agriculture including instruments as plows, harrows and yokes, and also in textile industries (parts of spinning wheels and weaving looms) and in wain production (axes, hubs, beams or skids). Folkloristic literature mentions in addition barrel hoops [32] and shoe soles [33] made of birch. Birch was seen as wood species having high strength and impact strength, high hardness, good sliding friction and good variation damping (Fig. 6).

In the past as well as today, maple (*Acer pseudoplatanus*) was appreciated because of its combination of comparable high hardness and high resistance against abrasion. Therefore, 40 % of all analyzed table toppings were made of maple and even today it is often used for floorings. What cannot be found in literature is the utilization of maple for spindle, cogs, axis and cylinder, all products highly challenging the material. However, the

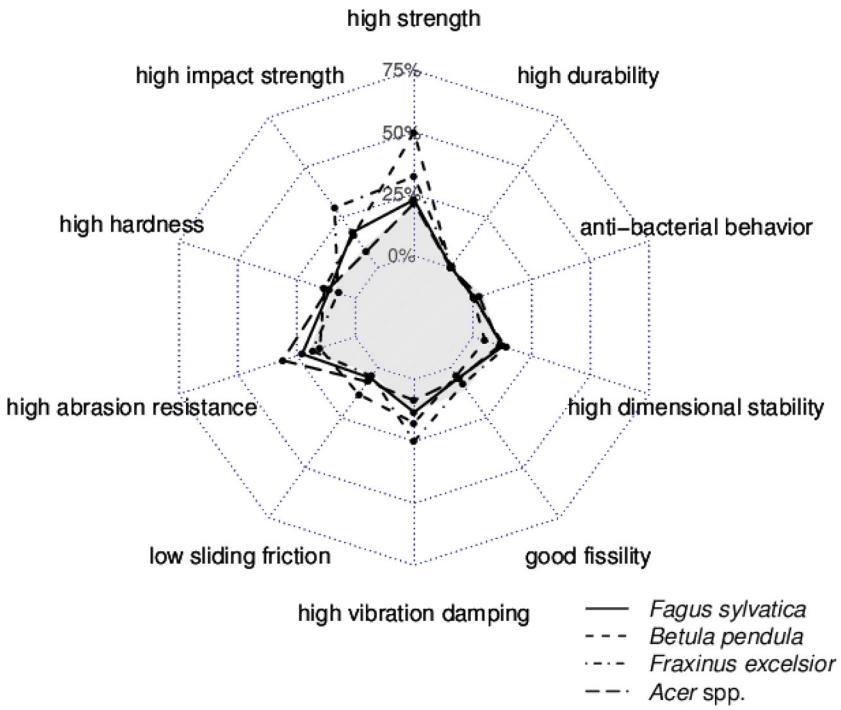

Fig. 6 Radarchart for four selected commonly used tree species showing the wood property index. The *gray area* is indicating the mean values of all 48 species

literature mentions additionally wooden shoes [34], flutes [19] and back frames to carry loads [35].

Ash (*Fraxinus excelsior*) is ranked in third place of the former most utilized wood species (Fig. 1). 12 % of all objects were made of ash. Even today ash is the species of choice if an elastic property as vibration damping or impact strength is needed (Fig. 6). The wood was thus found in wain production and for tool handles. Some wains were completely made out of ash. Furthermore ash is described in literature to be used for baskets [26], cider presses [36] and spindles [33].

To summarize, most wood species, except beech, were specialized. Almost all hardwood barrels were made of oak, 50 % of all planes were made of hornbeam (*Carpinus betulus*) and for carving wood lime (*Tilia* spp.) or stone pine (*Pinus cembra*) was used. Unfortunately it is not possible to describe all species in detail here.

Regionalism

Trading of wood was not common in rural areas in former times as there was a constant local supply of different wood species. A high variety of different wood species was available in all parts of Austria and those were carefully selected. Hence, only wood species having similar properties were substituted. In this investigation, some species were found to be regionally limited, e.g., Stone pine (*Pinus cembra*) in Carinthia, Styria and Tyrol, Scots pine (*Pinus sylvestris*) in Lower Austria and Burgenland and Cornelian cherry (*Cornus mas*) in Lower Austria.

Conclusion

Only a small range of native wooden species is currently utilized. Some rarely used wood species, however, show excellent wood properties. Especially shrubs often show a high wood density, followed by hardness and high resistance against abrasion. Fruit-bearing trees such as apple (*Malus domestica*), pear (*Pyrus communis*), or species belonging to the genus *Sorbus* could be challenged much more. Agreeing to their utilization in former times they show low sliding friction, high hardness and high strength. Most species are specialized for some application and should be used according to their specific properties.

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