FORESTRY, AGRICULTURE, AND FOOD INDUSTRY

RESEARCH ON WOOD PROTECTION PROBLEMS IN LATVIA

BRUNO ANDERSONS

The forest sector is an important area in Latvia from all three traditional aspects – economic (contribution to GDP, import-export balance, employment), ecological ("the Lungs of the Earth", CO_2 sequestration, renewable resources) and social (jobs, recreation). Sustainable, reasonable, economic use of wood in construction, and living environment is one of the traditional components of the sector, which is being given increased attention in connection with the wider use in construction and innovative solutions to wood materials. In this context, wood durability issues are not outdated.

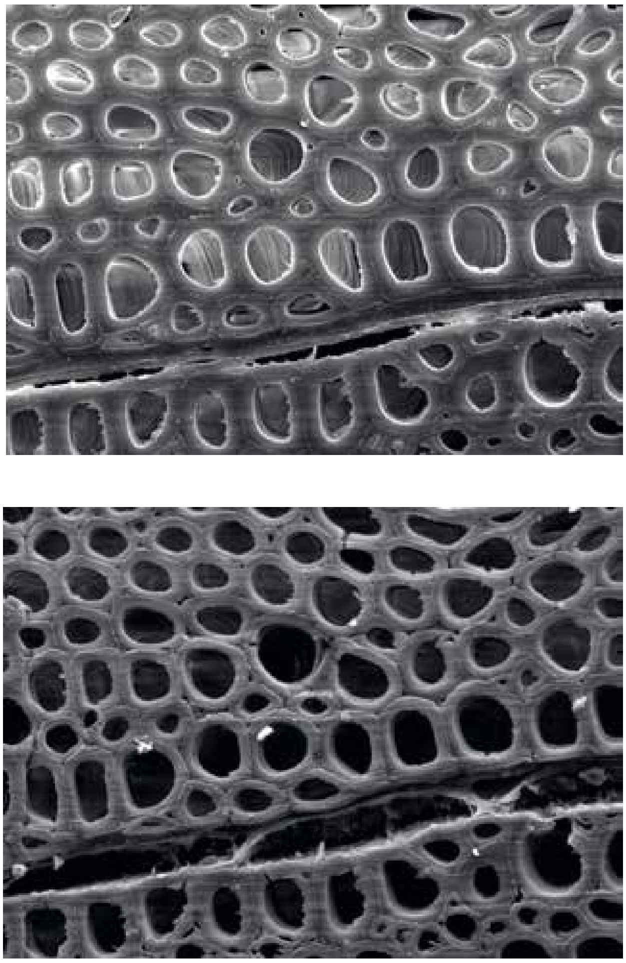
In the broadest aspect, a pioneer in wood research, including wood protection in Latvia, was Professor Arvīds Kalniņš (1894–1981). Already in the 1920s–1930s, he became intensely acquainted with forest and wood science, visiting all the leading centres of Europe. Along with forestry, wood as an important forest value, and the possibilities of its use from woodworking to chemical processing became a lifelong task of A. Kalniņš' research. After the Second World War, in 1946, under the initiative of A. Kalniņš, under the auspices of the Latvian Academy of Sciences (LAS), the Institute of Forestry Problems of the LAS was established. In 1966, it became the leading institute of the field throughout the USSR. Over time, the Institute transformed into the Institute of Wood Chemistry of the LAS (now – Latvian State Institute of Wood Chemistry, LSIWC), standing out in forest research as a separate organisation. Already from the first days of the foundation of the Institute, protection of wood became one of the strategic directions of research. The laboratory grew, developed, survived ups and downs, and survived the difficult times of science in the 1990s. Along with deep practical studies, such as the protection of supports of power transmission lines and sleepers, new wood preservatives and wood impregnation methods were developed, and wood biodegradation processes and mechanisms were studied. Extensive studies were conducted on the biodegradation of wood in outdoor conditions.

In Latvia, one of the five testing grounds of the USSR was established, in which the degradation of untreated and preservative-treated wood in outdoor conditions and soil depending on climatic conditions and wood species was investigated. Unfortunately, due to the "Iron Curtain", only in very rare cases the results gained wider publicity beyond the borders.

The knowledge accumulated in the course of many decades and the succession of research made it possible to adapt to the changing requirements in the field of wood protection, finding new solutions to urgent problems.

This year, the laboratory, along with the Institute, celebrates the 75th anniversary of its existence, like one of the world's leading wood protection research centres – Forest Products Lab at Mississippi State University. In 2020, the laboratory's research in the field of wood protection was announced by the LAS as one of the most significant achievements in Latvian science of the year.

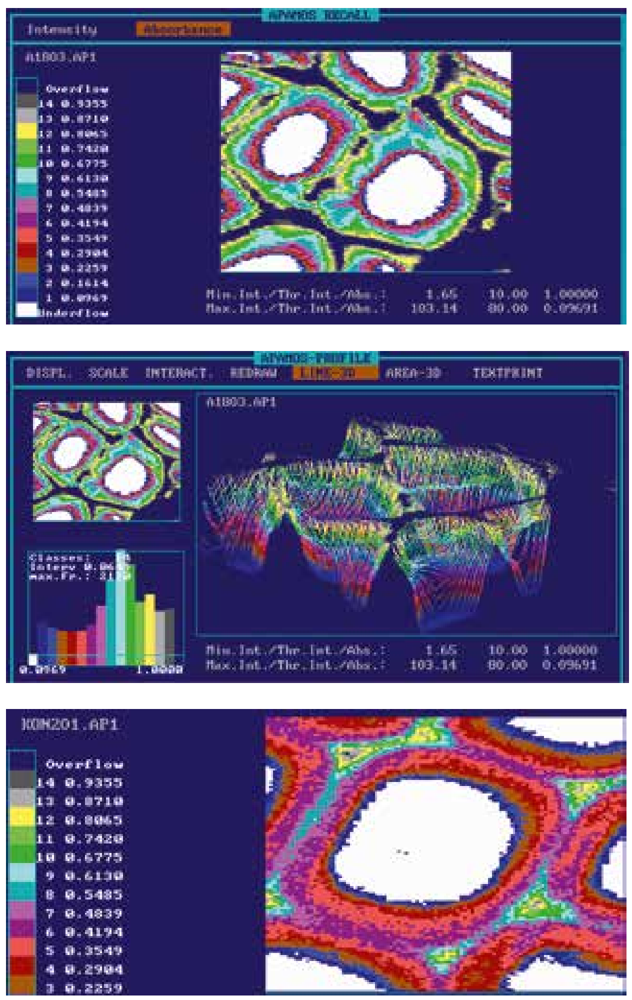
Currently, wood as a renewable material with unique technical characteristics, is gaining increasing application in construction. So that wood materials would be able to compete in the diverse modern building materials market, elimination of the drawbacks of wood is essential. Under the influence of environmental factors, wood is subject to abiotic and biotic degradation processes, which significantly shortens the service life. Every year in the world, several million m^3 of quality wood are used to replace damaged wooden structures and elements. To extend the service life, especially in the outdoor environment, wood is treated or impregnated with degradation limiting preparations.



Changes in the wood cell wall as a result of heat treatment (above – before, below – after modification)

Today, more and more stringent requirements are imposed on wood preservatives, similar to chemical compounds in other areas. At the beginning of this century, a significant breakthrough in the chemical protection of wood took place – the use of the most widely used arsenic and chromium compounds was banned, under the question is the use of creosote. As a matter of urgency, new, so-called second-generation preparations have been developed, which contain basic copper compounds as the dominant biocide, and organic biocides to broaden the spectrum of protective efficacy. However, these compositions are less effective, therefore, to ensure the economically justified service life of wood, higher quantities of preparations should be introduced into the wood, which, after the end of the service life, makes to classify wood as hazardous waste, with the corresponding disposal limits.

These problems in the protection of wood brought up to date the development of wood modification methods. Searching for new solutions, around 2010, the method of thermal modification of wood, studied in the 1930s, was brought to light. Its principle is the relatively gentle thermal treatment of wood in an environment with a low concentration of oxygen (in a water vapour or nitrogen medium, in a vacuum). From an environmental point of view, thermal modification (TM) of wood is a relatively environmentally friendly method of improving durability characteristics without the use of biocides. Surprisingly, the method of TM gave an impetus to industrial application within a short time, despite the incomplete knowledge of the properties and



Distribution of lignin in the cell wall before and after modification by the UMPS method aspects of use of the modified wood. Simultaneously with the industrial introduction worldwide, intensive improvement of TM methods and the study of TM wood was conducted.

During this time, also the Laboratory of Wood Biodegradation and Protection, LSIWC started the study of thermal modification processes and the optimisation of technological parameters for the improvement of biodurability and physical properties of wood of different tree species. There has been already relatively a lot of data on coniferous wood TM, so we started a detailed study of deciduous wood – alder, aspen, ash, and birch – TM in order to expand the possibilities of using these species in construction – indoors and outdoors. In the Laboratory, experimental pilot equipment (WTT, Denmark) was purchased for modification, and a comprehensive study of TM wood and wood composite materials (plywood) was conducted. To understand the TM action, the processes occurring in the material at the macro-, micro-, and sub-microscopic level were studied using chemical analysis and instrumental research methods (FTIR, Py/GC-MS, TGA, DSC, microscopy, etc.). The studies showed that TM wood, compared to unmodified wood, has a significantly different structure and chemical composition, and the autocatalytic reactions of the cell wall components occurring in the wood result in different physical and mechanical properties of the modified material, respectively, the service properties. In cooperation with foreign colleagues, wood changes as a result of thermal action were studied with modern research equipment – X-ray computed tomography (visualisation of changes in the microstructure of wood), UV microphotospectrometry (changes of the lignin component in the cell wall). When evaluating the results of the biodegradation of wood with rot fungi and analysing the activity of enzymes of these fungi in contact with unmodified and TM wood, a hypothesis was put forward regarding the changes in enzyme production as one of the reasons for the biodurabilty of TM wood. In order to be able to recommend the TM method for the production of wood products, as well as to interest buyers in the new product, the service characteristics of the resulting products – strength in static and dynamic loads, interaction with moisture and water, bioresistance against rot and colouring fungi, optical and surface parameters' changes in artificial and outdoor ageing conditions – were comprehensively described. As a result of the studies, the optimal technological parameters of TM for obtaining deciduous wood with improved and predictable durability characteristics were elucidated. When using wood for finishing, its decorative properties are also important. In outdoor conditions, the decorative properties of TM wood deteriorated – the brown colour obtained in the process became grey. A more detailed study of the spectral sensitivity of TM wood to solar radiation depending on the wavelength, considering the hydrophobic properties of the TM wood surface revealed the need to

Pilot plant for hydrothermal modification of wood (WTT, Denmark)

Dr. D. Cīrule prepares a test for artificial aging of wood in a chamber

Wood thermally modified in a pilot plant.

create protective coatings specifically for TM wood. To retain the decorative properties of the surface in outdoor conditions, a water-based coating composition for thermo-wood was developed. It is protected with a Latvian patent "Protective coating for thermally modified wood" [1].

In the process of the production and processing of thermo-wood, residues are formed. In the Laboratory, it was studied how they can be used in wood polymer materials (WPM), obtaining composites with higher biodurability, better water and moisture resistance properties and shape stability, compared to non-modified wood-containing WPM. The main results of the study are presented in publications in editions with high citation index [4–12], and a European patent application was filed [2].

The acquired knowledge about the transformations of birch wood in the TM process was used to study the possibilities of expanding the application of an industrially produced product – birch plywood. Specialists of Latvia's largest birch plywood manufacturer – JSC "Latvijas Finieris"

Dr. H. Sansonetti evaluates the aging of experimental samples under outdoor conditions participated in this study. Optimal stacking solutions were found in a TM chamber to assure the sheet quality, the characteristics of TM veneers were studied for the selection of optimal processing parameters, and the energy and material consumption in the thermal treatment of veneers was determined. The service properties of plywood, glued from TM veneers, and finished modified plywood were analysed in detail. Compliance with the requirements of standards for exterior plywood was established for the most important service properties (mechanical and adhesive strength). The results have shown that birch plywood glued together from TM veneers is the most promising for production. Potential changes in the properties when using TM plywood were assessed in ageing tests in a laboratory chamber and outdoor conditions, recording changes in colour and surface hydrophobicity, crack formation and biodegradability dynamics. Based on the results of the study, the license object “Method for improving the service properties of plywood” was formulated. The most significant results of research on TM plywood have been published in [14–17].

The results of several years of research allowed not only to find the optimal parameters of TM for different deciduous tree species, but also to assess the limitations of the application of the method. The obtained results allow using TM aspen, alder in places where high load resistance is not required (non-load-bearing structures), for example, in saunas, furniture and so on. It was found that the necessary parameters of TM processing to ensure high bioresistance against rot fungi significantly worsened the strength characteristics of the wood, especially the impact resistance. An objective assessment of the limitations of industrial production technologies led to the search for innovative, industrially, and economically acceptable solutions for improving the durability of wood, defining as an objective an eco-innovative competitive wood product with technical characteristics compliant with standards, and a predictable service life. A hypothesis was put forward that a positive result can be achieved by combining TM and impregnation (Imp) and obtaining a synergistic effect. This combined treatment, while retaining the strength properties of TM wood and ensuring biodurability, would allow lowering the TM temperature and at the same time introducing lower quantities of the wood preservative, which would benefit from the viewpoint of both environmental protection (lower amount of the used biocides, and simpler way of disposal after the end of the service life) and energy saving (lower energy consumption in the modification process). The task of the study was to obtain knowledge about the interaction between the two methods of wood protection, to understand the transformations of wood in both processes and the mutual influence, and to elucidate the service properties of the obtained materials. In only a couple of publications, we found reports of similar studies, but they were conducted on small samples of wood using small laboratory equipment. Our goal was to study the processes in experimental pilot plants, in conditions close to production, by subjecting samples of boards to processing.

An example of the use of thermally modified wood in facades

During the research on the wood of the most important coniferous and deciduous species in Latvia, namely, pine (*Pinus sylvestris* L.) and birch (*Betula* spp.), two sequences of both methods were tested: TM – Imp and Imp – TM. In TM, the lower TM processing regimes previously found for these species were used, which allows maintaining strength indices within acceptable limits.

For impregnation, a copper – organic biocide containing preparation was chosen, widely used for industrial chemical protection of wood. The concentrations of the working solution were selected in such a way that the quantities introduced in the wood were below the limit values established by the Nordic Wood Preservation Council (NWPC) for the corresponding group of preparations. The most important properties of use were determined for the materials obtained through both treatment sequences, the effect of TM on the quality of impregnation was assessed, and the optimal treatment sequence and the optimal parameters for each wood species were defined. The penetration by diffusion, distribution, and fixation (formation of water-insoluble compounds) of the biocide in wood were scrupulously studied, which depend on the treatment and correlation of these factors with the properties of biodurability. Potentially more promising products were characterised by their components' composition and properties (strength, interaction with moisture and water, colour stability, biocide fixation/ leaching, bioresistance in laboratory tests), ageing and biodurability in outdoor tests were evaluated. When summarising the data obtained, the most promising double processing sequence and optimal parameters were selected. The most important results are reflected in publications and confirmed in the Latvian patent "Wood impregnation method" [3].

As part of the project, the methodology and software for developing Life Cycle Inventory (LCI) and Life Cycle Assessment (LCA) was mastered as a fundamentally new direction for the Laboratory. LCI was developed for pine and birch wood grown in Latvia, and LCA – for the most potentially promising wood materials obtained by combined processing. LCI is one of the main and most voluminous parts of LCA; it contains data characterising the life cycle of the product (energy consumption, emissions, material consumption, etc.) in connection with the impact of these factors on the environment. A new approach to the collection of LCI data for wood raw materials was developed, taking into account the time factor at the production stage of the product. This has so far been ignored in the field of wood products evaluation, assuming that the production process of the product under analysis does not change in time and that the extraction of the raw material is approximated to the present situation. Such a statistic approach is appropriate for products that have a relatively short production cycle and do not undergo significant changes in the production technology and principles. In the case of wood products, such assumptions lead to significant discrepancies, given that the growth of wood in the production process of wood products (from seed to tree of felling age) takes a very long time (50 years or more). The project's newly developed LCI data collection methodology for a more and relevant characterisation of the production process is based on an interdisciplinary approach, integrating data from forestry, environmental science, and wood harvesting history. Within the framework of the project, based on the newly developed approach, LCI was compiled for pine and birch growing in Latvia, which have reached the felling age (101–121 years for pine and 51–71 years for birch), thus demonstrating the applicability of interdiciplinarity. A significant role in the creation of LCI was played by the cooperation with specialists of the JSC "Latvian State Forests" and the Latvian State Forest Research Institute "Silava". It should be noted that the data sets created for birch and pine are innovative and unique, and can be used for further assessment of the environmental impact of various Latvian wood products. These sets of wood raw material data, further combined with the inventory data of a particular wood product, can be used not only for the creation of a product LCA, but also for the Environmental Product Declarations of wood construction products, which will be and in some cases is already a vital tool for ensuring competitiveness in the market.

Using the collected data, LCA for Imp-TM birch and pine wood was developed and an economic assessment was conducted. When assessing the costs of the wood raw material, TM and Imp processes and human resources, an economic confirmation of a potentially more promising combined treatment in Imp-TM has been obtained. When determining the total costs of the products, it is concluded that the largest part of the costs consists of the costs of wood, human resources, and electricity consumption in the TM process. When switching to industrial production, the costs of a wood product will decrease several times, considering a significantly larger amount of the material to be processed in one cycle [18–23].

The current laboratory projects focus on a number of topics: modelling of environmental conditions in museum premises for preserving the funds' wooden artefacts; ensuring the quality of impregnation of glued wood; improving the antibacterial properties of wood and expanding the use of wood in public, including health settings.

An important area of activity of the Laboratory is the cooperation with manufacturers – both by advising on impregnation and thermal treatment issues, and by regularly conducting impregnation quality testing. Manufacturers use the laboratory equipment for feasibility studies for the development of new preparations or process optimisation. Within the framework of the projects in the competence centre of the forest sector, practical issues urgent for manufacturers, regarding the improvement of product characteristics, environmental safety and economic efficiency, are being resolved.

Over many years, the Laboratory has cooperated with cultural heritage managers, including both research and identification of fungal and insect damage, and consultations on pest control plans and activities, and prevention of repeated damage. Among the cooperation partners, there are both churches of different denominations and museums, including the Ethnographic Open-Air Museum of Latvia and Rundāle Palace Museum.

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ABOUT THE AUTHOR

Dr. chem. **Bruno Andersons** is a senior researcher and head of the Wood Biodegradation and Protection Laboratory of the Latvian State Institute of Wood Chemistry, full member of the Latvian Academy of Sciences. His main research interests are focused on wood structure and wood chemistry; a tree in a living environment; degradation of wood and wood materials due to various factors; wood protection, modification; cultural heritage of wood, its research and preservation.

FOOD SCIENCE IN THE FACE OF NEW CHALLENGES

INGA CIPROVIČA

Each scientific discipline has its own challenges in the rapidly changing world, its own goals, objectives, and development scenarios. Food science is no exception in this context. And the key question is "Will we continue to enjoy the wide range of food available, will edible insects become a reality in our daily diet?"

As the world's population increases, so does the demand for food. It was recognised already in 2009 at the World Summit on Food Security that global food production would increase by 70% by 2050 to feed the population of around 9 billion people [1]. Climate change and water shortages are already threatening the production of agricultural raw materials for food processing. Population growth will pose significant challenges to the sourcing of food due to limited agricultural land and agricultural production volumes affected by climate change, reduced or depleted fish resources, and the waste of food by-products throughout the food chain. It is anticipated that the annual consumption of grain for processing of food and animal feed will increase by 1 billion tonnes and the consumption of meat – by 200 million tonnes. Provision of such volumes is only possible when applying science-based knowledge on the production of agricultural raw materials and knowledge-intensive food technologies [2]. Thus, the emphasis in food science will have to be put on addressing these issues in order to avoid global food crises.

Currently, food science focuses on the processing of raw materials into new, high-quality products, the development and implementation of new technologies and materials, processes and equipment to improve the safety and validity of food products. The challenges for science in the future will be the supply of food raw materials, including the use of non-traditional raw materials, the increasing application of biotechnological processes for the production of raw materials/products, and the need to improve the ingredients and products composition and nutritional value. As a result, synergies between food science and technology will be increasingly promoted, with close links to nutrition science, to ensure not only a low-cost, easy-to-use and palatable product, but also a nutritiously balanced and valuable product for everyday consumption [3].

Food science must also become increasingly aware of its close connection with the changing economical, demographic, cultural, and ethnic traditions of the world, including the health needs of the individual. Food scientists need to take very seriously the ability to feed the world, with a view on the significantly increasing population by 2050.

What needs to be done or what can we do? Firstly, there is a need to restore public trust in science and

Dr. sc. ing. Ilga Gedrovica. Earthworm protein in food production: Future?

Performance of the food scientists of Latvia University of Life Sciences
Source: https://www.llu.lv/lv/veiksmes-stasti-llu

to demonstrate the importance of food for public health through research, to reduce the populism of pseudoscience and pseudoscientists about the harmful effects of commercial products on consumer health. Secondly, food scientists need to engage in dialogue with the public, to maintain conversation in order to gain public trust in their work. In addition, it requires new knowledge, insights, and competencies.

In their work, food scientists have proposed reducing or replacing fat, food additives (especially synthetic), sugar and salt, using of non-traditional ingredients or raw materials for classical products production, at the same time trying to ensure that the product tastes good, smells good and has other characteristics that customers like.

Scientists have proposed solutions to replace animal fats with fully processed trans-fat free oils with a higher concentration of monounsaturated fatty acids. Scientists have created sweeteners with a high degree of sweetness and sugar substitutes from natural substances to reduce the consumption of sugar in the diet. Salt is reduced in products wherever possible. At the same time, the traditional taste, smell, and texture of the products, which are popular with the consumer, have not been changed. Given the efforts of food scientists to formulate healthier, great-tasting, more convenient and widely available products, obesity, diabetes, food contamination, food allergies and intolerances, and food scarcity are a reality today.

Source: https://www.hsph.harvard.edu/obesity-prevention-source/obesity-trends/

The numbers speak for themselves. In 2020, 39% of adults worldwide (over 18) were overweight and 12% were obese [4]. That is more than a half of the world's adult population.

In addition, obesity has almost tripled since 1975 [5]. Moreover, 10% of the world's population suffer from hunger [4].

These numbers are impressive, seeing them we have to ask the question "Have the efforts of food scientists allowed us to achieve the intended results?" Great taste, convenience, and product value are no longer strong enough arguments to choose specific products. This means that we have to face new challenges, different from what we have faced so far.

We need to understand the impact of the developed products (raw materials used in their use, changes of nutrients in processing, newly formed compounds, and their effects) on our microbiome, organisms as a whole and on the planet. There is still insufficient knowledge about the bioavailability of food nutrients, so special attention needs to be paid to determining the causal links between their effects on the individual's body and health in general [6]. It is also the greatest scientific challenge not only for food science, but also for nutrition, physiology, etc.

We need to go beyond the classical disciplines in food science. This means breaking down existing scientific frameworks to incorporate new scientific knowledge about food development, availability and significance in nutrition. Thus, the wider integration of knowledge and the role of an interdisciplinary approach in food science will only increase.

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ABOUT THE AUTHOR

Dr. sc. ing. **Inga Ciproviča** is a professor at the Faculty of Food Technology, Latvia University of Life Sciences and Technologies, and full member of the Latvian Academy of Sciences.