Wood in food industry - Potential applications and its limitations

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In past wood has been used as traditional material for many applications in food industry but other materials like plastic and stainless steel have taken its place. There are several studies which show that wood can be as hygienic as others materials and even more, some species of wood have antimicrobial property. In food industry of dried egg pasta wooden trays are used for drying the fresh pasta. Traditionally, wood especially oak was used; however in recent years polyethylene terephalate materials became dominant in food industry. We made hygiene evaluation of wooden and polyethylene terephalate trays for pasta drying. Materials were compared to total number of aerobic microorganisms, *Enterobacteriaceae*, *E. coli*, Moulds, Yeasts and *S. aureus*. The study proofed the hypothesis that material has influence on CFU, since on plastic frames for pasta trays much more microorganisms are developed than on wooden ones ($p<0.001$). Wood in some food industries like pasta drying, wine and fruit production, bakeries, ect. can be safe as other materials, but has to be cleaned and maintained properly to minimize microbiological hazards in process of food making.

Keywords wood; food industry; microbial hazard

1. Introduction

In recent years, we have observed a growing concern for safe and healthy food. Especially important is the understanding the food safety, covering everything from legislation to producers and consumers [1]. Essential is a holistic approach that takes into account entire food chain, ranging from field to table, and represents a major potential source of factors that can compromise food safety. Food safety is so important that every link in the chain is defined, controlled and overcome [2]. Food safety chain can be quickly interrupted due to various factors in the agro food supply chain [1].

We have to realize that the food may be contaminated with a variety of microorganisms at all stages, from production, processing and also in preparation [3]. Despite the principles of the Hazard Analysis Critical Control Point (HACCP) system, there are some hazards in final products which can result in food poisoning [4]. HAACP system is a preventive system that enables the identification of microbiological, chemical and physical agents that may to represent a health risk. It sets up the necessary measures and establishes permanent monitoring at points in production and trade of food, where the risk can occur [2]. Before planning a HAACP system at least two basic conditions have to be established; good hygienic practices and good manufacturing practice [5].

Beside the basic principles of hygiene, more attention should be paid to the materials used in the food industry. Interactions between microorganisms and contact material surfaces play an important role in different branches. In some of them we want to maximize adhesion of microorganisms on surfaces (eg. municipal wastewater treatment plants with attached biomass) and in other cases minimized (eg. food industry, health care) [6].

The adhesion process is governed by physical and chemical interactions between microorganisms and surface and represents the first step by attachment [7]. Different contact materials are in contact with different types of microorganisms and their forms which can cause harm to consumers' health because of their pathogenic properties [1] or great economic losses due to food spoilage and reduced quality of products [8]. Materials have different characteristics for adhering and loading for various contaminants like bacteria, yeasts, fungal and bacterial spores and viruses. Due to characteristic attachment / adhesion they serve as vehicles to transfer contamination vectors from place to place. If the contact materials allow microbes to survive than the probability to transfer contamination to the next recipient is very high, what has strong impact on safety and quality of final products or service [9].

Since contact materials are in regular and permanent contacts with substrates or final foods in production process, there is high probability to acquire and load surface contaminants from contact materials into/onto products. Understanding all this processes and their impact, it would be possible to foresee possible outcomes and thus prevent negative impact on food/drug product safety and quality [10].

2. Wood and food through history

Wood in food industry has a prehistorically meaning as a tool when preparing the meal as a heating agent, storage facilities as well as universal food contact material for distributing food (wooden primitive plates). Wooden shipping

containers have traditionally been used for a range of solid and liquid foods including fruits, vegetables, tea, wines, spirits and beers. They offer good mechanical protection, good stacking characteristics and a high vertical compression strength-to-weight ratio [11]. Wood is a hard, fibrous structural tissue found in the stems and roots of trees and other woody plants. It has been used for hundreds of thousands of years for both fuel and as a construction material. It is an organic material, a natural composite of cellulose fibres (which are strong in tension) embedded in a matrix of lignin which resists compression. Wood is sometimes defined as only the secondary xylem in the stems of trees, or it is defined more broadly to include the same type of tissue elsewhere such as in tree roots or in other plants such as shrubs. In a living tree it performs a support function, enabling woody plants to grow large or to stand up for themselves. It also mediates the transfer of water and nutrients to the leaves and other growing tissues. Wood may also refer to other plant materials with comparable properties, and to material engineered from wood, or wood chips or fibre. There is a wide range of wood species and the most commonly used are form continental origin: poplar (*Populus*), pine (*Pinus*), spruce (*Pinaceae*), beech (*Fagus*), ash (*Fraxinus*), oak (*Quercus*), etc. French law has a regulation in 1945 updated in 1980, which includes a positive list of wood species suitable as food contact material. The following woods are accepted for contact with all food types: birch (*Betula*), fir (*Abies*), Douglas fir (*Pseudotsuga*), acacia (*Acacia*), poplar, alder (*Alnus*), hornbeam (*Carpinus*), chestnut (*Castanea*), ach, olive trees, maritime pine and oak.

Wood and food can be sometimes the same thing, like: wood apple fruit, chestnut, cinnamon, bamboo plant, clove, mustard, vanilla, etc. Wood in a gas form is often use in food industry for smoking meat with purpose to preserve it and reach unique sensory characteristic of meat. Smoking is the process that is applied to many cured meat and mat products with primary purpose of developing characteristic aroma and flavour, preservation, creating of colour and formation of a protective skin on emulsion type of sausages and protecting from oxidation [12]. Nevertheless wood is an important materials when aging of wine and more important aging of whiskey and other distillates in oak barrels. Wood in contact with food is traditionally used not only in packages of singles use or reusable packaging but also in cutting boards and countertops, utensils and kitchen utensils, kebab skewers, toothpicks, ice pops, wine barrels etc. According to the compilation of wood scientific studies conducted by Schönwälder [13] and Milling [14], they find that the negative trend on the qualities of wood in contact with food is reserved along 90s, when an increased research in favour of wood results from the progress of evaluation techniques and better understanding of phenomena related to foo contact materials.

3. Wood applications in food industry

The food processing system involves a complex, concentrated and dynamic chain of activities that begins with production of raw agricultural commodities on farms, orchards and ranches, and then moves from value-added processes to manufactured products, and then to retail food stores and food service establishments where they are merchandised, prepared and sold to consumers [15]. It is important to understand the uniqueness of each sector of the food system when considering the role of sanitation and food safety in the food industry [16-18]. Today we manage food safety through good practices at different levels of food production, distribution and consumption. The maintenance of food safety in a food supply chain can be easily broken down because of different kinds of barriers or simple misunderstanding among stakeholders, including consumers [6,19].

Wood is mainly used in packaging, transport, handle, preserve and give added value to the following food products and sectors:

- Fruit and vegetable
- Fish and other sea food
- Wine and spirits
- Oils
- Cheese and dairy
- Meat and conditioned meat
- Bread and bakery
- Dried fruits.

Many consumers are concerned about chemicals entering food during farming, processing and packaging. They rely on the producers and the control authorities to guarantee that the product is safe. If, for instance, a new substance enables the pack designer to achieve a more striking and eye-catching pack decoration and a food packer wants to use it to promote the product, the consumer accepts this because of trust in adequate control [20]. EU legislation requires that compliance of food contact materials with the legal requirements must be assured at each stage of the supply chain. The process has to respect good manufacturing practice (GMP), and for this purpose GMP is defined as the tool to ensure compliance. Communication through the production chain is an essential part, clarifying which work has been done and what are delegated to subsequent business stages.

The food supply chain can be compromised during production, processing, preparation, service and transport, and therefore any food may be exposed to biological, chemical or physical agents with the potential to cause illness [21]. Failure during food processing, especially time and temperature abuse, may allow survival and proliferation of

pathogenic bacteria, moulds and the production of toxins [22]. To prevent adverse effects on health, it is important that every link in the food supply chain understand the importance of good hygiene practice, good manufacturing practice, and the HACCP system. Hygienic and functional acceptance of wood in food industry and households depends from many factors like quality, type and treatment of wood. The microorganisms could proceed more deep in transversal cuttings (more than 4 mm deep) than in wood being cut in longitudinal way as reported by Prechter and co-workers [23]. Adetunji and Isola [24] studied the biofilm formation on wood, stainless steel, and glass surfaces, with the results demonstrating that wood encourages biofilm formation due to its porosity and absorbency, which can entrap organic material and bacteria. The surface properties also play an important role in bacterial adhesion. Generally, any surface is vulnerable to biofilm development including plastic, glass, metal, wood, and food products. The adhesion to the surface is also dependent upon the physicochemical properties of the surface such as texture [25], surface charge [26], hydrophobicity, pH, temperature [27], and nutrient composition of the preconditioning solution [28]. For instance, the research of Sinde and Carballo [29] found that Salmonella and Listeria can attach in a higher numbers to hydrophobic surfaces than the hydrophilic ones. Many years wood in food processing was not advised to use because of cases that studied wood as a microbiological risk [24, 25].

The wood in contact with food is regulated so that should not be treated with chemicals for preservation or phytosanitary treated. In some cases in wood packaging manufacturing it only suffers a final dying process (reducing of moisture below 20%). Anyway, there is a clear difference between the level of content of certain natural compounds from the wood or its traces, and the level of those that may result from treatment or contamination. On the other hand, in wood packaging is not common the use of special coatings. This is more common in household and kitchen utensils of wood, sometimes using natural coatings allowed to improve their properties (solvent, waxes and oils). As many other material wood material constituents (mainly natural volatile organic compounds) migration into food is not regulated by EU. EU has only established migration limits from plastic materials. The wood structure is complex and mostly porous. Capillary properties and ability to retain moisture in the fivers, far from being a problem, impart desirable properties. The rapid disappearance of surface contamination in the wood poses a less risk of cross contamination to other non-porous surfaces such as plastic.

The antimicrobial properties of several plant-associated substances, such as flavonoids, tannins, and essential oils have received a lot of attention during recent years as potential preservatives, disinfectants, and therapeutic agents [30-32]. One of the most studied individual substances is (E)-resveratrol (3,4′,5- trihydroxystilbene), a compound present in red grapes and berries [33, 34]. It has both antifungal and antibacterial properties and, furthermore, its practical use as an antimicrobial compound [35].

4. Risk assessment and use of wood

As the case today with most materials, there is a significant deficiency of legislation and methods for characterization of wood food contact material when compared with plastic. This is mainly due to the safety of wood and food security priorities of the European Union. However, there are many studies [13, 21, 36] on the hygienic properties of wood, which confirm that wood is as good as other materials for use in the food industry, either on pallets, packages or container. There is lack of references to the authorization of resinous and tropical woods. Notwithstanding the use of properly cured softwood without health problems for years. Fruit and vegetables pallet boxes or tablets to cure cheese are good example. The pine and spruce are traditionally used in contact with fish, meat and dairy products in the Nordic countries.

In April 2004 the European Parliament adopted regulation (EU) No. 852/2004 on the hygiene of foodstuffs. This has to apply all EU food businesses from 1st of January 2006. The main change to the law relates to food safety management systems i.e. risk based methodologies to ensure the safety of food [37]. Food business operators shall ensure that all stages of production, processing and distribution of food under their control satisfy the relevant hygiene requirements laid down in the Regulation (EC) No. 852/2004. In the same year EU adopted Framework Regulation on materials and articles intended to come into contact with food Regulation (EC) 1935/2004 and two years later Good Manufacturing Practice for materials and articles intended to come in contact with food Regulation EC 2023/2006. European legislation on food contact materials is transparent and comprehensive regulating general legislation and legislation on specific materials.

Wood has been a traditional material for many applications in the food industry. But today the usage of wood in the food industry is under debate and wood is getting discriminated in many sectors - in utensils, interiors and buildings as well as in pallets and packaging. The main reasons stated are:

- Risk of splinters
- Wood is a porous material
- Lack of cleaning and/or sanitation methods

Since 1998 a Nordic project is going on with the aim to find out basic facts about the hygienic properties of wood. This report will give some information about Hazard Analysis and Critical Control Points (HACCP) and Good Manufacturing Practices (GMP), some general guidance for handling wooden pallets and packaging in the food industry

and information about some methods for cleaning and sanitation in order that wooden pallets and packaging can be used in the best way. Recent studies both in the Nordic countries and in Europe have shown that wood is as good as any other material for many purposes in contact with food. In order to keep a good hygiene there are some general rules for handling and storage of pallets and packaging. Use clean, dry pallets for the food industry. Wooden pallets should not be stored unprotected outdoors in order to avoid biological, physical and chemical contamination. Keep pallets separated – special pallets for hygienic zones Use pallet inverters. To avoid contamination a possible, cheap and easy solution is to use wooden pallets with a slip-sheet on top. When depalletising one pallet the receiving pallet also has a slip-sheet on top. The pallets can be kept in separate zones and the slip-sheets can be made of different materials, expendable or reusable. One method to clean pallets is to use high pressure water sprinkling [13, 36].

The pallets can be pasteurised by using :

- Heat treatment by adding an additional drying cycle in a kiln
- High temperature treatment
- Microwave technology, which seems to be one very promising method. This method is used in the egg industry but need to be adjusted for other food sectors.

Wood as a material that enters the production facilities has to be taken in consideration during risk assessment analysis. The level of potential risk (CP or CCP) is depending to the step of production at which the wood or wood particles (example ice cream sticks) enters the process. Entering the wood as wooden pallets in packaging area where the final product is already packed in primary foil or other material represent less risk for contamination (biological, physical, chemical) of food than entering the wood sticks for ice cream. Therefore is important to use wood where is needed and represent better solution than use of other material (pasta static drying on trays). As stated above the wood mainly represents the physical risk to food when maintained properly.

5. Good hygiene practice of wood in process of pasta making

The most difficult and expensive stage in the manufacture of pasta products is the drying process [38]. Drying of egg pasta is preservation process and it can be named as critical control point. The aim of drying is to reduce the content of water. Since the migration of water from the internal to the external layers and so to the surface takes place by capillarity, the pasta must maintain an appropriate porosity in relation to its current moisture required by regulation [39]. In food industry of dried egg pasta (e.g. spaghetti, elbow macaroni, screw-shaped pasta, spirals, butterflies, shells, ribbons, etc.) producing wooden and Polyethylenetherephtalate (PET) trays are used for drying the fresh pasta.

The small and medium size dried pasta production facilities are usually equipped with trolleys loaded with trays which are manipulated totally manually by workers. Plastic tray weight 3.25 kg when wooden one only 2.10 kg so the difference between one tray is 1.15 kg. Standard load per trolley in discontinuous or batch production is 21 trays per trolley so the difference or extra weight that has to be manipulated production process is 24.15 kg per trolley.

Key features

- Pinewood structure
- Food-safe, anti-hydrolysis polyester mesh
- Maximum resistance and versatility with minimum weight
- Three standard heights: 30, 55, 70 mm
- Interchangeable with other plastic, aluminium or steel trays

Wooden frame suitable for drying pasta and similar products. The wooden frame and polyester mesh are strong and hard-wearing. Maximum versatility guaranteed by three standard models. Available in three sizes: for lasagne, for standard short-cut pasta and for large pasta shapes (e.g. large shells).

Main technical features:

- Perimeter frame with galvanized screws to guarantee the secure fitting and durability of the mesh over time
- 3 aluminium reinforcing tubular sections (ø 10 mm)
- Polyester mesh with continuous row of stapling
- Sliding rail to ensure correct stacking of trays on the trolley
- Food-safe, anti-hydrolysis 100% polyester mesh

Since in drying room extreme conditions are present, a material used is such processes must be durable. From technological point of view plastic is unsuitable since is twisting, expanding and shrinking under drying room conditions. In heating stage of draying process plastic trays can expand so intensively that cannot be moved in trolley and on other hand in stage of cooling they are so shrinking that can fall out of trolley. Nevertheless the plastic trays are also heavier than wood what represent unnecessary burdening for workers. On market it can be found also trays made of aluminium which are lighter but costs are extremely high. Wooden trays are more rigid and more resistant to conditions changes and are also lighter. Average air temperature in drying chamber is 65 ºC. Time of drying variety due

to pasta type, however is between 6 hours to 14 hours and relatively humidity is decreased from 28 % - 34% to lower than 12 % and the water activity in final product is lower than 0.6 [40].

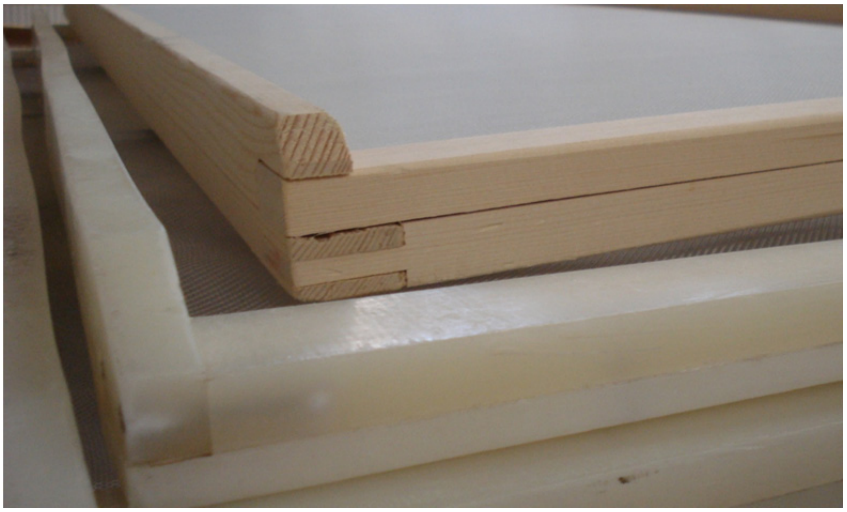

Fig. 1 Wooden and plastic trays for pasta drying

It is very important that the problems are tackled systematic with the use of hygiene evaluation study as a four-stage learning process [41]:
a) problem identification/defining the question(s);
b) gathering information systematically;
c) reviewing the information;
d) reflecting on the results and/or taking remedial action. Only in this way we could plan or design effective interventions for hygiene improvements.

Hygiene evaluation of wooden (*Abies* spp.) and plastic - PET trays for pasta drying were analysed by swabbing and compared due to total number of aerobic microorganisms (TAC), *Enterobacteriaceae*, *E. coli*, Moulds, Yeasts and *S. aureus*. In research 105 plastic and 105 wooden trays were tested. In each trolley, made form stainless steel 21 trays were inserted. Therefore the 1st, 11th and 21st trays were swabbed in area 20 cm^2. Sterile swabs on plastic stick made of cotton were prepared with 5 mL of sterile 0.9 % NaCl solution. Plastic and wooden trays were washed in the industrial washing machine using washing program of: 5 minutes of flushing with cold water, 5 minutes washing with 65 ºC hot detergent solution , 3 minutes flushing with hot water 85 ºC and drying for 5 minutes with dry steam (105 ºC). Pasta was produced from durum wheat semolina, whole pasteurized egg and water on continuously line using premixing, kneading and pressing pasta dough trough brass model (die diameter 1.0 mm). Fresh pasta was added on trays and dried 8 hours according to drying program and at the end of process, before manual handling, the swabs were sampled.

In the Table 1 results from TAC, Enterobacteriaceae*, E.coli*, moulds, yeasts and *S.aureus* from swabs sampled from two types of trays made from different materials are given. Results show that average bacteria on wooden trays are lower than on plastic.

Table 1 Comparison of bacterial colonization on PET and wooden material

	Wood		PET		Δ	95 % CI		t-value	*p*-value
	$\bar{X}$	S_e	$\bar{X}$	S_e	$\bar{X}$	lower	upper		
TAC	2.885	0.313	91.942	7.300	-89.057	-150.220	-27.894	-2.904	0.004*
S. Aureus	0.285	0.005	13.942	0.628	-13.657	-19.154	-8.673	-5.296	1.33^-6*
Entero-bacteriaceae	2.985	0.358	148.228	34.133	-145.243	-430.199	139.707	-1.0168	0.312
E.coli	/	/	/	/	/	/	/	/	/
Moulds	0.028	0.004	0.500	0.034	-0.472	-0.763	-0.179	-3.422	0.001*
Yeasts	0.014	0.003	6.200	0.822	-6.186	-13.047	0.676	-1.7984	0.076

Legend: $\bar{X}$ – average; S_e – standard error; Δ – difference in average; CI-confidence interval; * statistical significant difference at $p < 0.05$.

Similar results can be obtained on Figure 2 that represents percentage of positive swabs. In all samples form PET much higher percentage of positive were identified that in wooden.

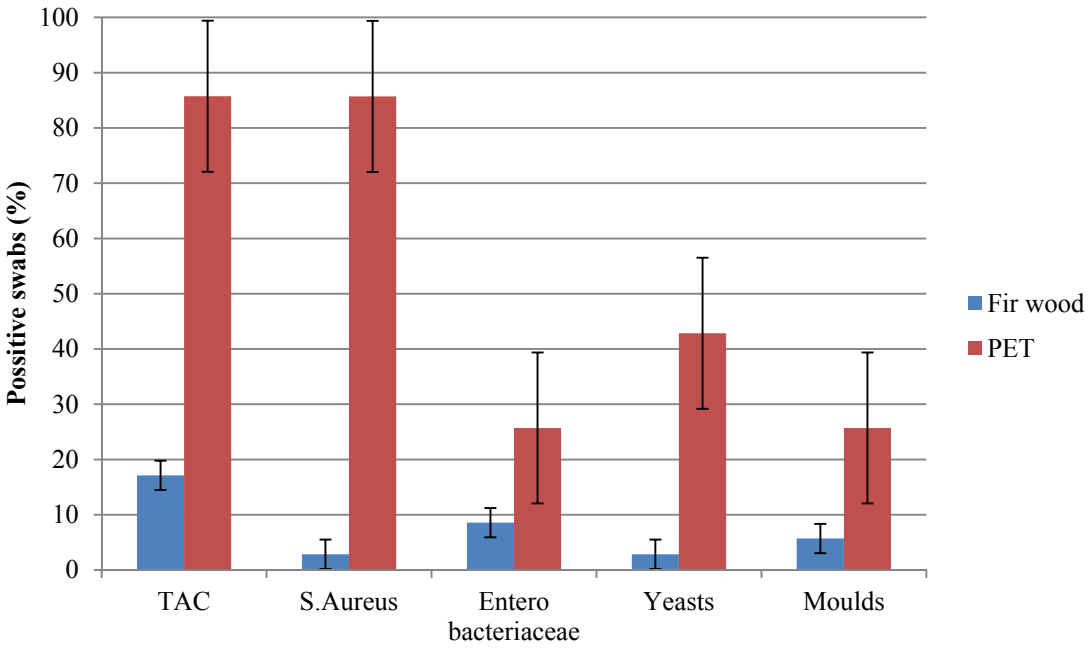

Fig. 2 Percentage of positive swabs on fir wood and PET trays

The results of our research shows that number and species of microorganism are statistical different on PET and wood ($p < 0.05$). According to the results obtained can be confirmed that the material have statistically significant impact on the presence of colonies in CFU/20 cm^2, except for the Enterobacteriaceae and Yeasts, where the statistically significant difference is not present. It is evidently that the materials of pasta tray have influence on bacterial number and that wood is more hygienic material than PET.

6. Future trends of wood use in food industry

In the near past when fundamental knowledge from food safety and HACCP was implemented many actions was made in quite short time with lack of practical experiences. Therefore in many cases the producers adopted some thesis or actions that were based on practical knowledge from part of food industry like meat production and processing. Wood as food contact material was from one moment not suitable for use in kitchen, food production, restaurants etc. and almost all participants replaced wooden frames, cutting boards, tables, with plastic one, what resulted many problems which haven't existed before. Plastic materials were more expensive so producers lower the frequency of replacing, maintaining them what resulted decrease of materials hygiene. Effort from many studies shows that use of wood instead of plastic materials have some benefits in particular food industry such as dried egg pasta, bakery, and bakery shops. In the future the combination of good practice, environmental knowledge and food safety knowing should guide the development of food production systems. Nevertheless the wood as a material is renewable, cheap to produce and after use represent lower impact on environment than plastic and is cheaper to decompose.

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