Nordic Industrial Fund - **Nordic Wood 2**
center for innovation and commercial development

## Project P 98076 "Wood in the Food Industry"

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Part report no. 1

# Literature review:

## The suitability of materials used in the food industry, involving direct or indirect contact with food products

Danish Technological Institute — Trätek — Icelandic Fisheries Laboratories — Fiskeriforskning

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***FOREWORD***

Wood used to be the most common material for packaging, workbenches, shelves, tools, buildings, interiors etc., in the food industry in the Nordic countries. The use of wood has however decreased, and other materials like plastic, concrete, stainless steel and aluminium have taken its place. The reason for this negative development seems to be declining market demands, partly caused by legislation in Europe and elsewhere.

Despite this, nearly 1,5 million cubic meter of timber per year is used for pallets and packaging in the Nordic countries. These products are hence of great importance for the wood industry as the alternative production of packaging materials may be chips for pulp production. Based on that background, a Nordic research project was initiated to find out more about the behaviour of wood in contact with foodstuff.

The main object of the project has been to collect data regarding wood products and their substitutes when used in the food industry, and to find suitable methods to identify and measure the growth of bacteria on wood and their substitutes.

This report is the first in a series of reports where the results from the Nordic Wood 2 project ”Wood in the Food Industry” (no. 98076) are presented. This part report is a literature review on the suitability of materials used in the food industry, involving direct or indirect contact with food products.

The project is funded by the Nordic Industrial Fund through their program Nordic Wood 2 which is an R&D program for the Nordic wood industry. The Nordic timber and woodworking industry and national funding authorities in the Nordic countries have raised additional funding.

The project has a steering group with the following members:

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|---|---|---|
| - Heine Aven, chairperson | Aven AS, | Norway |
| - Marianne Moltke, deputy chair person | Norwood AS, | Denmark |
| - Lennart Svensson | AB Gyllsjö Träindustri, | Sweden |
| - Bjarni Ingibergsson | Limtré h.f., | Iceland |

The research is carried out by The Danish Institute for Technology, Icelandic Fisheries Laboratories, The Norwegian Institute for Wood Technology, The Norwegian Institute for Fisheries and Aquaculture and The Swedish Institute for Wood Technology Research.



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Representatives from food surveillance institutions in the Nordic countries are invited to the project meetings. Pallet manufacturers, sawmills, woodworking industries and users of wooden constructions, pallets and packaging are also involved.

The following industries, organisations and research institutes have contributed with their know-how and services:

Denmark: Norwood A/S, Dansk Træemballage A/S, Dansk Teknologisk Institutt, Træteknik (DTI)

Iceland: SÍF. h.f., Limtré h.f., BYKO h.f., Samskip h.f., Vörubrétti h.f., Icelandic Fisheries Laboratory (IFL)

Norway: Aven AS, Høylandet treindustri AS, Saltfiskforum, Fiskeriforskning, Norsk Treteknisk Institutt (NTI)

Sweden: AB Gyllsjö Träindustri, Åsljunga Pallen AB, Strandbergs Trä och Pallindustri, Trätek, Institutet för träteknisk forskning,

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This part report no.1 is written by: Hélène L. Lauzon, Icelandic Fisheries Laboratories

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## *1. INTRODUCTION*

Wood has been used for many centuries in the preparation of food products. In Iceland, wood is still been used for the production of salted fish, fish drying as well as convective structure in processing plants and shipping aids on board for overseas transportation. Recently, the use of wood in the food industry worldwide has been diminishing, especially in the areas of food processing, packaging and transportation aids. This is mainly because of modifications brought to the regulation. Because wood is a porous and absorbent material where organic matter along with bacteria can become entrapped, cross-contamination is a main concern. With the development of new materials during the last decennies, various polymers have become the work surfaces of choice despite little research to support the change. It is claimed that these plastic surfaces have all the advantages of wood without its disadvantages.

Sanitation of food contact surfaces is an essential operation in the food industry because such surfaces can spread microbiological contamination in products. The efficacy of sanitation of food contact surfaces depends, among other factors, on the materials used in their manufacture. Some bacteria have the tendency to adhere to hard surfaces, multiply and produce extracellular polymeric substances, forming a so-called biofilm. Other bacteria may become entrapped in such a biofilm and even be protected from active compounds used during sanitation. In fact, attachment of microorganisms to food contact surfaces is a concern in the food industry because previous studies have shown that these cells appear to be more resistant to sanitizers (Schwach & Zottola, 1984; Frank & Koffi, 1990; Wirtanen & Mattila-Sandholm, 1992a, b). Pathogenic bacteria are particularly of concern as biofilm formation may become a nest for them, facilitating their proliferation on contact surfaces and consequently their transfer to the products being processed.

The choice of a proper material that will be in direct or indirect contact with the food being produced is not an easy task. Various factors must be considered. The



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following are examples:

(1) the intended use of the material: cutting, support, packaging purposes, ...
(2) the inherent characteristics of the material (porosity, absorbency, strength, ...)
(3) the durability of the material/ ease of maintenance and repair
(4) the nature of the food product: liquid, solid, fatty or not
(5) the cleanability of the material
(6) its cost

The literature was reviewed in order to assess the research conducted on materials used in the manufacture of direct and indirect food contact surfaces, compare these surfaces with respect to the above mentioned factors and determine the areas of research where further work is required.

## *2. PARAMETERS AFFECTING THE RESULTS OF PUBLISHED RESEARCH WORK*

The methodology followed in a study is very critical to the results obtained. It is therefore important to consider it carefully when comparing studies. Since the body of research on the current matter is not very large, a special attention should be brought to the following considerations before a conclusion is drawn:

(1) type of material tested: Is a specific material description given? Is it new or scored?
(2) nature of food product in contact with surface: Is it solid or liquid? Fatty or not?
(3) details on prior use and cleaning procedure of material
(4) contamination of material and its level: Is it a laboratory or natural contamination?
(5) residence time between contamination and sampling: Has the material dried out?
(6) environmental conditions of the experiment: temperature, humidity, ...
(7) details on bacteriological sampling and analytical methods

In some cases, experimental details may be lacking. Also, laboratory results must be carefully and sensibly extrapolated to industrial conditions.



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## *3. WHAT IS THE MOST SUITABLE MATERIAL FOR FOOD CONTACT?*

Mainly 3 different groups of materials with direct food contact have been mentioned in the literature and these include various hardwood species, synthetic (plastic and hard rubber) and stainless steel surfaces. Materials with indirect food contact, i.e. as superstructures, were iron, wood, plastic, glazed brick, concrete and stainless steel. There is of course no one perfect material that will suit all possible applications. Different materials may be used for different purposes. In fact, one should be aware of the inherent characteristics of a certain material to correlate them to the intended use and find the most suitable material for that particular purpose.

### 3.1 Inherent characteristics of a material and its intended use

Different types of polymers have been developed and used for various applications in the food industry, mainly to replace wooden material. Polymers mentioned in the literature reviewed include polyethylene (PE), polystyrene (PS), polyacrylic (PA), polypropylene (PP). polyvinyl chloride (PVC), polyester, polyurethane, smooth and rough nylotrol, Teflon and Plexiglass. Plastic materials have been used for direct contact purposes, such as cutting boards and conveyor belts, as well as indirect contact such as pallets. For the former use, they have been claimed to be non-absorbent, not prone to cracking, nor bending or warping, but easy to clean. However, some researchers (Gilbert & Watson, 1971; Ak *et al*., 1994b; Abrishami *et al*., 1994) have reported that scarred plastic surfaces became more difficult to clean. Delanay (1975) found that smoothing the surface with a belt sander corrected the situation. Otherwise, replacement was necessary.

Stainless steel is of course a common contact surface. This metal is widely used because of its smoothness, durability and low oxidative properties. Hard rubber is also encountered.

Wood has been widely used in the food industry because of its durability, good performance and low prices. However, it is a porous material and can easily absorb blood, fat and moisture. Decontamination (cleaning and sanitizing) can therefore prove to



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be difficult to achieve properly. Some of the wood species mentioned in the literature are hard maple, ash, basswood, beech, birch, butternut, cherry, oak and American black walnut.

Early, unpublished studies on decontamination of wood cutting surfaces apparently showed that satisfactory results could be achieved with chlorine sanitizers (Anon., 1965; Levac & Matula, 1973; Matula & Chappel, 1974). Interestingly, Gilbert & Watson (1971) compared wood and plastic cutting boards after being contaminated with ground beef and decontaminated by immersion in warm water (45-50°C) containing an anionic dish detergent, and found that plastic was more easily cleaned. Also, decontamination of knife-scarred surfaces was less effective but still favoured the plastic. On the other hand, another unpublished report (Delanay, 1975) compared plastic, rubber and wooden cutting boards from commercial meat processing establishments in Wisconsin and found a greater proportion of plastic and rubber than wooden surfaces with high bacterial loads following cleaning. Miller *et al.* (1996) compared wooden and PE cutting boards contaminated with ground beef and found the bacterial attachment and removal were similar on and from both types of surfaces. Differences in the results obtained may probably be explained by different contamination, cleaning and sampling methods used as well as the surface state of the material being tested, i.e. whether new or damaged/ scored.

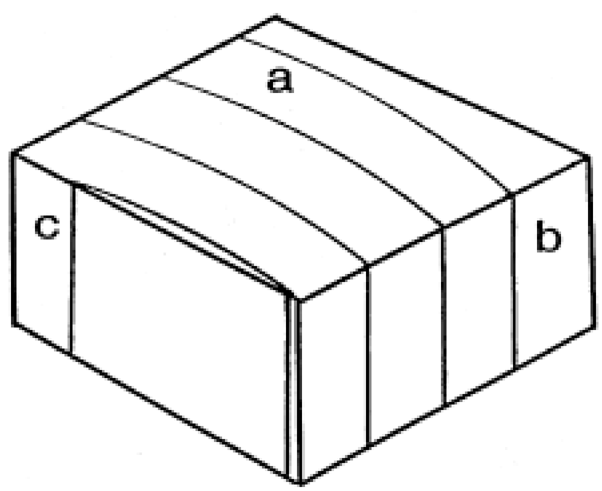


FIGURE 1. *Grain orientation in wood structure, based on location of annular rings: (a) end, (b) edge, and (c) face.*



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Wood structure is complex. The grain orientation is based on location of annular rings and can be defined as end-, edge and face grain (Figure 1). Wood fibers possess capillary properties and a high water-retention capacity. Kampelmacher *et al*. (1971) pointed out the heterogeneous structures of wood. Conductive tubules (xylem) and fibers are arranged alternatively in more or less dense arrays (annular rings). Typically, moisture conductivity is greatest from an end-grain surface, less from edge grain, and even less from face grain. According to Kampelmacher *et al*., a chopping block with fibers perpendicular to the surface (end-grain) can allow for bacterial penetration several centimeters into the wood.

In the studies of Ak *et al*. (1994a, b), low recoveries of bacteria from laboratory contaminated wooden boards brought about questions on whether the disappearance of the bacteria meant their non-viability due to drying out or because of antibacterial properties of wood, or whether the possibility that their unaccessibility once entrapped into the wood structure was due to the sampling technique. Park & Cliver (1996) developed an innovative sampling method that made use of the capillary properties of the fibers to detect bacteria inside the wood. Unfortunately, they did not use this perfusion method to evaluate the viability of bacteria following a normal cleaning procedure, but rather to assess the use of microwave heating to kill the entrapped bacteria, which they succeeded. Abrishami *et al*. (1994) showed that 88% of the cells inoculated onto dry, new wood adhered to it after 10 min. In fact, it was seen by scanning electron microscopy (SEM) that many bacteria were associated with the cytoplasmic regions of dried structural and vegetative elements of the xylem tissue. On the contrary, previously conditioned wood (wet), whether new or used, did not absorb the inoculum very well as the bacterial recovery was high. Moreover, Abrishami *et al.* demonstrated by a direct viable count-SEM method that about 75% of the cells adhering to the wood structure (new or used) were viable for up to 2 h following inoculation. Based on microcosm assay on wood dust/chips and plastic pieces, they concluded these materials to have no beneficial nor deleterious effect on the viability of bacterial cells, despite a noticeable reduction (31%) of cells when incubated with wood chips.



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The antibacterial properties of wood have therefore been questioned. Miller *et al.* (1996) tested 8 wood species and found that the aqueous ash extract was inhibitory to *E. coli* O157:H7. Red oak and cherry extracts had a slight inhibitory activity. However, Ak *et al.* (1994b) also reported the inhibitory properties of wood, but concluded that due to extreme washing during the experiments as well as failure to extract an aqueous active compound, these properties were not due to water-soluble compounds. The findings of Galluzzo & Cliver (1996) agreed with those of Ak *et al*. (1994b) as oak leachates were not bactericidal towards *Salmonella enteritidis*, in contrast to the oak shavings and chips tested. Even various solvent extractions were conducted on the wood, but the antibacterial effect was not diminished. A similar antibacterial effect was seen with filter paper. Their results therefore indicated that the mechanism of disappearance of *Salmonella* from oak was rather physical than chemical. In fact, it could be a combination of adhesion and drying effect on the cells.

Studies on the adherence and removal of bacteria on and from various materials can provide important basic information. As previously discussed, conditioned (pre-wet with water) wooden surfaces were found to be less absorbent than dry surfaces, but similar to plastic surfaces (Abrishami *et al*., 1994). Plastic and wooden surfaces were found to be similarly contaminated by ground beef (Gilbert & Watson, 1971; Miller *et al*., 1996), whereas bacteria were shown to be less adherent to stainless steel and more easily removed as well (Snyder, 1997). Biofilm studies of *Listeria monocytogenes* conducted by Krysinski *et al.* (1992) demonstrated that cell attachment occurred at a similar rate on either type of materials tested (stainless steel and plastic conveyor belt chips). In the case of bacterial removal, it was usually easier from new plastic than wooden surfaces when simple cleaning procedures were performed (Gilbert & Watson, 1971, Snyder, 1997). However, procedures including some mechanical action contributed to a better removal of bacteria from the surfaces tested, especially if used materials (Gilbert & Watson, 1971; Snyder, 1997). Eugster *et al*. (1980) developed a method to assess the affinity of the surfaces for lipids. Such knowledge can be useful for the food industry to choose proper surface materials as well as to evaluate their ease of cleaning and the efficiency of detergents. For instance, smooth nylotrol had a greater affinity for lipids than high density PE, whereas rough nylotrol physically entrapped fat.



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Only one study evaluated the use of different materials for superstructures in meat processing plants (Worfel *et al.*, 1995). The levels of mesophilic bacteria was assessed in the condensates formed on these indirect contact surfaces following processing. The most to least contaminated surfaces were iron > wood > plastic, glazed brick and stainless steel. However, the differences in microbial counts were not significant.

## 3.2 Durability and maintenance of material

Little work has been done on the durability of the materials following extended use. The wood used for cutting board purposes is sufficiently hard to have a reasonable life without damaging the cutting edge of knives (Gilbert & Watson, 1971). Wood has good maintenance properties and can be planed as required. Conditioning of wood was shown to be beneficial, as it decreased bacterial penetration (Abrishami *et al.*, 1994). Refining of wood to decrease its porosity as well as the use of an oil treatment could be useful in increasing its hydrophobicity. However, mineral oil treatments, as tested by Ak *et al.* (1994a), were found to have little effect on water uptake. When subjected to total immersion in hot water containing alkaline detergents, wood tends to expand and contract, and is said to become prone to disintegration (Cooper & Dyett, 1967).

Ruosch & Hess (1977) recommended that plastic cutting boards be examined for cuts and scratches, as recently planed plastic cutting boards were easier to clean. Gerigk (1966) showed that plastic (unspecified type) wears faster than wood, because wood swells when wet, smoothing out grooves, cracks and incisions.

Plastic pallets have been introduced to the food industry due to the cross-contamination risk by their wooden counterparts, although some major technological shortcomings are known to occur (Anon. 1974). Fatigue (deformation of the pallet due to loading) and creep (accelerated and irreversible deformation) are important ones. It follows that plastic pallets often require interior reinforcement, which adds to the cost. Also, the sensitivity of plastic to heat and cold influences its performance over time. Storage under freezing temperatures can cause shattering of the pallet, whereas too much



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heat can lead to its deformation.

### 3.3 Nature of the food product

Food residues on contact surfaces can of course contribute to the presence and proliferation of adhering bacteria. This organic matter that becomes impregnated into porous and/or scarred surfaces, will provide some protective effect to the adhering bacteria. To simulate the build-up of fat residues, Ak *et al*. (1994b) coated wooden and plastic working surfaces with chicken fat . The fat uptake was less on new boards, but was greater on plastic than wooden surfaces. Also, fat removal was easier from wood than plastic, still worst for used boards. It should be noticed that a higher recovery of bacterial cells was seen on fat-coated wooden boards than non-coated, suggesting a decrease in surface porosity of the wood when covered by fat. Similarly, better recovery was obtained with fat-coated plastic boards. In fact, these findings correlate with those of Abrishami *et al*. (1994) who showed that oil-based inoculum was not absorbed as quickly by dry wooden surfaces as the water-based one used by Ak *et al*. (1994a, b). Also, Abrishami *et al*. showed that an used wooden cutting board with its fibers covered by layers of organic matter, as seen under SEM, did not absorb the bacterial inoculum as quickly as new wood. Therefore, food residues may fill the imperfections of the contact surfaces, but also become a nutritious template and contribute to the growth of bacteria.

### 3.4 Cleanability of material

Various cleaning procedures are reported in the literature. The simplest one involved rinsing/brushing meat-contaminated plastic and wooden cutting boards with water which significantly removed a high level of bacteria (Miller *et al*., 1996). Interestingly, use of chemical cleaners did not statistically improve the performance. Similarly, Abrishami *et al*. (1994) reported the use of an automatic dishwasher with only cold water to remove *E. coli* contamination from new and used boards, new plastic boards being the most easily cleaned. Parallely, Snyder (1997) concluded that a pre-wash step was practical in reducing the initial bacterial load on stainless steel, plastic and wooden surfaces prior to washing and that a vinegar solution used to wipe the surfaces was an efficient sanitizer, especially on plastic. Nevertheless, used plastic boards were



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more difficult to clean (manually with hot water and detergent) than wooden ones, especially when coated with fat (Ak *et al*., 1994b). Kampelmacher *et al*. (1971) recommended cleaning cutting boards with an abrasive alkaline detergent and a sanitizer. Gilbert & Watson (1971) reported that physical cleaning was the most effective on meat-contaminated wooden and plastic boards (new and used) and that disinfecting with hypochlorite reduced the bacterial load only slightly, offering an additional line of defence. These findings exemplify the fact that the efficiency of cleaning and disinfecting agents is greater when soil is initially removed by pre-washing, ensuring a better use of the chemical agents on the remaining bacterial load.

Recent trends of longer production runs in the food industry, with short intervals for cleaning and sanitizing as well as environmental considerations, imply that agents used must be efficient at low concentrations with short contact times. Dhaliwal *et al*. (1992) verified the efficiency of two quaternary ammonium compound-based disinfectants against biofilms formed on different materials (stainless steel, PVC, Teflon, beachwood, Plexiglass and rubber). The compounds tested acted similarly on both Gram positive and negative bacteria, but the bacteria became more resistant to the compounds when adhering to a surface. Holal *et al*. (1990) actually reported similar results. Moreover, Dhaliwal *et al*. found that bacteria attached to PVC, Teflon and Plexiglass were more sensitive to the disinfectants tested than when adhering to wood, stainless steel and rubber. Surprinsingly, stainless steel and wood surfaces were not properly sanitized with 2% concentration of disinfectant with a contact time of 15 min. (well above manufacturer's recommendations). They therefore concluded that disinfectants differed in their surface bactericidal activity.

Also, Frank & Koffi (1990) studied biofilms of *L. monocytogenes*. They found that the bacterial load adhering to glass decreased by 2-3 log following its exposure to the sanitizers tested (BAC and DBSA), after which the remaining cells survived a 20 min-exposure, as opposed to a total disappearance of viable cells in suspension after 30 sec. at the lowest concentration. Heating the sanitizer to 70°C weakened the adherent cells and contributed to a greater cell reduction (< 5 log), but with still a surviving population.



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Interestingly, a heat treatment at 55°C virtually reduced the number of suspended cells, whereas it had no effect on adherent cells. Another study (Krysinski *et al*., 1992) on the resistance of *L. monocytogenes* cells adhering to stainless steel and plastic conveyor belt chips to cleaners and sanitizers demonstrated that the efficacy of sanitizers depended upon the material studied. The resistance to the compounds was greatest on polyester/polyurethane chips > polyester > stainless steel. Actually, most compounds were active against cells adhering on stainless steel, except for chlorine and iodophor. To the contrary, none of the sanitizers tested could inactivate the cells attached to polyester/polyurethane chips. Cleaning of stainless steel removed all attached cells, but most remained on plastic. The most effective sanitizers on attached cells were acidic quaternary ammonium compound, peracetic acid, chlorine dioxide. Less effective were mixed halogens, acid anionics and fatty acid sanitizers. The least effective ones included chlorine, iodophor and a neutral quaternary ammonium compound.

## *4. METHODS OF BACTERIAL RECOVERY*

Various methods of sampling prior to the bacteriological evaluation of surfaces were mentioned in the literature reviewed. Wood destructive methods, such as scraping, usually gave the highest recovery rates (Kampelmacher *et al*., 1971; Ruosch, 1981), whereas the efficiency of many other methods (swabbing, agar sausage, contact agar plating, soaking/shaking in broth, scraping/rinsing of surface, and modified spray gun) depended on the mechanical action involved.

Higgins (1950) reported a higher bacterial recovery rate when using soluble calcium alginate than cotton-wool swabs. Also, swabbing is generally considered to be more sensitive than direct sampling by agar-impression methods (Gilbert, 1970; Mossel *et al*., 1966), but the type of surface and bacterial status are important factors in comparing these methods. Tebbutt (1991) compared alginate swabs to agar-contact plates for sampling food premises, with a special interest for *E. coli*. He found that by doing a double sampling of an area by swabbing it first and then using an agar-contact plate, *E. coli* could be detected by both methods as opposed to sampling first with agar-contact plates followed by swabbing the same area where *E. coli* could only be detected from the



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contact plates. These findings can probably be explained by the fact that bacteria distributed on the surfaces may occur as microcolonies in biofilms (Holah *et al*., 1989). It follows that swabbing first may have caused breaking up of colonies, leaving viable cells on the area sampled that in turn were picked up by the following sampling method, i.e. agar-contact plates. On the other hand by reversing the order of the sampling methods, it is probable that most microcolonies (the most easily dislodged ones) were picked up by the agar-contact plates, possibly leaving too few readily available cells to be detected by the subsequent method, swabbing.

Use of sonication did not improve the bacterial recovery from wood and plastic boards tested (Ak *et al*., 1994a). The perfusion method (Park & Cliver, 1996) was innovative and quite appropriate for experimental wooden surfaces since it allowed for the extraction of entrapped cells. It made use of the capillary action of the wood structure, by pushing the bacteria from the interior to the surface of the structure. Bacterial recovery can also be achieved by soaking the contaminated side of the material tested into a sterile microbiological medium for a pre-determined time (Ak *et al*, 1994 a & b). Plating of the recovery medium would provide an estimation of the contamination. However, in the case of wood and according to the wood cut type, there is a chance that such a recovery method will actually push the surface-trapped bacteria to the interior of the wood instead of delivering them to the medium. Such a method would obviously lead to the underestimation of the surface contamination.

Superstructure can be considered as an indirect food contact surface. Cleaning and maintenance of such surfaces is crucial to avoid the development of undesirable microbial contaminants that can contaminate the food during production and its packaging material, therefore spreading out the contamination all over the processing plant. Evaluation of the superstructure contamination can be done by most of the methods previously mentioned. Worfel *et al*. (1995) assessed the presence of microorganisms in condensate from non-food contact surfaces in meat processing facilities by 2 methods. One involved the use of a sterile aluminium pan (with a collecting surface of 889 $cm^2$) hung at a distance of 20 to 30 cm from superstructures constructed of iron, stainless steel and wood to collect dripping condensate during a whole production period. A phosphate



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buffer solution (100 ml) was used to rinse each pan and 1 ml plated on microbiological media. Similarly, another method used aluminium pans but these were hung at 4 to 10 cm from the structures investigated for 4 consecutive days. The results showed that the former method was inadequate due to the limited quantity of condensate accumulating over the production period and its probable evaporation. The second method allowed for the collection of condensate and splash water that occurred during cleaning.

## *5. CONCLUSION*

Many laboratory studies have been conducted, but there is surely a lack of field studies to confirm most of the findings. As discussed by Carpentier (1997), experiments with laboratory suspensions may not be representative of conditions seen in the food processing plants where a diverse microbiota as well as a pre-determined environment exist. This is especially true when a mono-cultured inoculum used is water-based and therefore far from representing the food conditions.

Otherwise, it can be said that based on the discussed studies, contamination of surface materials was comparative. Stainless steel was the most easily cleaned surface, whereas plastic was generally found to be cleaner than wood, unless fat deposits occurred. However, used plastic surfaces were more difficult to clean than used wooden surfaces, especially in the presence of fat deposits. Plastic wears faster than wood, offering openings to foreign contaminants. Therefore, it is important to consider a strict control of its maintenance if it is supposed to be safer to use than wood. It was also shown that conditioning of wood or its refinement to increase its hydrophobicity contributed to a lesser penetration of contaminants. But many of these studies were aiming at home environments and it is probable that industrial use of wood cutting surfaces would not be as favorable due to little drying of the wood following its use. Also, because of the 3-dimensional structure of wood different cuts surely give different results. The low bacterial cell recovery from wood following its contamination was mostly explained by the sampling method used since most entrapped cells (75%) were found to stay in a viable state within the wood structure for at least 2h. Further work is required to assess whether further drying would contribute to a safer utilization of wood as a cutting



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surface. Otherwise, wood may be a proper material for indirect food contact, assuming good treatment and maintenance. Some of the reported studies suggested some antibacterial properties of wood, most probably due to physical inhibition.

Carpentier (1997) pointed out that there was a lack of information regarding the optimum conditions for the use of wood. Also, there is little knowledge on whether scraping can actually be used as a maintenance practice to contribute to the hygienic condition of wood. More information is required to establish a sound cleaning/sanitizing procedure for wood as well as other materials according to their expected used. It has been shown that food residues can interfere with the efficiency of cleaning and sanitizing procedures and contribute to biofilm formation. This is an important area for future research. More importantly, the methodology used to contaminate, sample and analyse surface contact materials should be well considered.

A wide range of information has been brought up and perhaps a little bit confusing. The main thing to remember is that there is probably no one best material for contact surfaces, as pros and cons have been discussed, but one should evaluate each situation independently and make a decision based on sound knowledge.



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