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Part report no. 9

Hygienic properties of wood

-Field studies on wooden pallets and wood in constructions (gluelam)

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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. One of the reasons for this negative development seems to be a declining market demands, partly caused by legislation in Europe and elsewhere.

But in spite of this, nearly 1,5 million cubic meters of timber are used for pallets and packaging in the Nordic countries each year. These products are very important 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 when used in contact with foodstuffs.

The main object of the project has been to collect data about 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 one in a series of reports where the results from the Nordic Wood 2 project no. P 99095 ”Wood in the Food Industry” are presented.

This partial report gives information about hygienic properties of wooden pallets and wood in constructions (gluelam).

The project is funded by the Nordic Industrial Fund through the 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:

- Dag Aasheim, chairperson — Otte Sag & Høvleri AS
- Peter Jensen — Dansk træemballage AS, Denmark
- Stefan Nilsson — Åsljunga Pallen AB, Sweden

- Bjarni Ingibergsson Limtré h.f., Iceland

The research is carried out by the Danish Institute for Technology, the Icelandic Fisheries Laboratories, the Norwegian Institute for Wood Technology, the Norwegian Institute for Fisheries and Aquaculture and the Swedish Institute for Wood Technology Research. Representatives from food monitoring institutions in the Nordic countries are invited to attend the project meetings. Manufacturers of pallets, sawmills, woodworking industries and users of wooden constructions, pallets and packaging are also involved.

The participants would like to express their warm thanks to the Nordic Industrial Fund and the national funding authorities in Denmark, Iceland, Norway and Sweden which have contributed to the funding of the project.

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SUMMARY

There is an ongoing debate today about the use of wood in the food industry and, in many ways, wood is being discriminated against. A Nordic study, financed by Nordic Wood, Nordic Industrial Fund and national funds has been carried out with the aim of finding out the facts about the hygienic properties of wood. New information, from studies which have been carried out in Europe, have shown that wood is as good as any other material for many purposes in the food industry. This study showed that gluelam is as good as galvanised steel regarding hygienic properties for the use of wood in constructions. Material used in construction of plants is not as important as other factors, such as avoiding condensates, and that cleaning is important to all types of material. The hygienic properties of six different types of wooden pallets (pine, spruce and beech) and two types of plastic pallets (PE and HD-PE), used for storing and transporting food products, were compared. The difference between wood and plastic pallets was negligible when determined by analysis of variance ($p>0,05$). The pallets were cleaned with high-pressure cold water and the cleaning efficiency was evaluated very good for all kind of pallets tested. This research does not justify the distinction made between the hygienic qualities of tested wood and plastic pallets. The important thing to remember is that there probably does not exist any one particular optimal material for contact surfaces, after all pros and cons have been considered, but one should evaluate each situation independently and then make a decision based on a sound knowledge. One must however always bear in mind which standards or regulations are in place regarding this matter in each country.

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1. INTRODUCTION

The debate about if and how wood should be used in food industry continues to this day. Since 1998, a study, financed by the Nordic Wood, the Nordic Industrial Fund and national funds has been carried out with the aim to find out the basic facts about the hygienic properties of wood. The research is carried out by the Danish Institute for Technology, the Icelandic Fisheries Laboratories (IFL), the Norwegian Institute for Wood Technology, the Norwegian Institute for Fisheries and Aquaculture and the Swedish Institute for Wood Technology Research. Representatives from food monitoring institutions in the Nordic countries are invited to attend the project meetings. Pallet manufacturers, sawmills, woodworking industries and users of wooden constructions, pallets and packaging material are also involved.

Traditionally, wood has been a widely used material for many applications in the food industry. Today however wood is often being discredited as a suitable material by many sectors - in utensils, interiors and buildings as well as in pallets and packaging. The main reasons which are being stated are:

- risk of splinters
- wood is a porous material
- lack of cleaning and/or sanitation methods

The main reason for this negative attitude towards wood seems to be caused by food legislation and how it is being interpretated in Europe and elsewhere. Because wood is a porous and absorbent material, where organic matters, along with bacteria, can become entrapped, cross-contamination is a main concern. With the development of new materials during the last decades, various polymers have become the work surfaces of choice, although research to support the change is insufficient. For example, it has been claimed that these plastic surfaces have all the advantages of wood but none of its disadvantages.

The use of hardwood in contact with food is permitted for many purposes. To give an example, beech is commonly used for ice cream sticks. In this case the wood must be both strong and feel good in the mouth and may not give any flavour to the ice

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cream. Furthermore, the wooden stick is isolating and prevents the ice cream to melt too fast. Beech is also frequently used in cutting boards and various kitchen utensils.

In the U.S. regulations, hard maple or an equally hard, close-grained wood may be used for cutting boards, cutting blocks, bakers tables and utensils such as rolling pins, doughnut dowels, salad bowls and chopsticks (Beyer and Guðbjörnsdóttir, 2002).

Many studies have been done on the hygienic properties of wood (Lauzon, 1998). In some recent studies there are new results supporting that wood is not less hygienic than other materials.

The food industry needs information about the hygienic properties of the materials used in the processing environment in order to be able to evaluate the suitability of the relevant materials, e.g. wood. The choice of the proper material which will be in direct or indirect contact with the food being produced is not an easy task. Various factors must therefore be considered. The following are examples:

(1) The intended use of the material (cutting, support, packaging, etc.)
(2) The inherent characteristics of the material (porosity, absorbency, strength, etc.)
(3) The durability of the material/ ease of maintenance and repair
(4) The nature of the food product: liquid, solid, fatty, etc.
(5) The cleanability of the material
(6) Cost

The aim of this study was to evaluate the hygienic properties of wood used in the food industry and to test some cleaning methods for wood. This is the partial report no. 9 concerning use of wooden pallets and gluelam in the food industry.

2. MATERIAL & METHODS

2.1 Experimental layout

In this study, three different surveys were carried out.

2.1.1 Wood in constructions - gluelam

Firstly, one hygiene survey was carried out in a salt fish warehouse - on gluelam and on

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galvanised steel surfaces which have been up to 6 years in the building. Secondly, a laboratory test on gluelam and galvanised steel was performed where the bacteria, recovered from the samples, was tested after contamination with a known number of bacteria isolated from fish processing. Finally, an experiment was carried out where six differently treated gluelam samples (1-5) and one sample of galvanised steel (6) (Figure 1) were placed at three different locations in a salt fish warehouse, at one location in a caviar processing factory and in a humid and a dry working room at IFL.

1A. 1 x Kopal primer (water based) and 2 x Kopal acrylic painting (water based)

1B. 2 x Kopal epoxy painting (water based

2A. 2 x Parquet painting (water based)

3B. 2 x Epoxy painting (oil based)

4A. 2 x Kjörvari 14 (decay preservative)

5. No treatment

6. Galvanised steel

Figure 1. Gluelam samples in salt fish storage

The test pieces were placed in a vertical position. Microbiological samples were taken in the salt fish warehouse every two months over a period of 16-months. Two samples were taken from each type of surface (in total 42 samples each time) during the first three samplings and after that the two samples were pooled together and tested as one sample (in total 21 samples). In the caviar processing factory, the sampling was carried out after 4 months and again after10 months and, finally, at the IFL the samples were taken after 2 and 4 weeks.

Micro-organisms were recovered from the surface using the swabbing and the contact

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methods according to the methods evaluated in the first partial report and regarded as suitable for wood (Lorentzen et al, 2000). In the beginning, a rapid method (Adenosine Triphosphate (ATP) - bioluminescence) was used to estimate the bacterial load. The results obtained by using ATP and the contact method were inconsistent and will therefore not be discussed further in this report.

2.1.2 Wooden pallets for storage and transportation.

The pallets studies were performed in a salt fish warehouse, in a supermarket and in a dairy (figure 2). Six different types of wooden pallets were used; skid pallets made of pine, planed pine, spruce, planed spruce, a perimeter based pallet with bottom deck, blocks and stringer boards of beech and softwood deckboards and a pallet with a solid deck of high temperature dried (HT) spruce. The pallets were manufactured by pallet manufacturers in Sweden, except the HT-spruce pallets which were assembled in Iceland. Two types of plastic pallets were used – an Icelandic Polyethylene (PE) pallet with a solid deck (the white pallets in Figure 2-4) and a French High Density Polyethylene (HD-PE) pallet (the red pallets in Figure 2-1). All the pallets came directly from the manufacturer and had not been used before the field tests, except for the pallets used at the dairy.

Figure 2. Wood and plastic pallets in a salt fish storage, supermarket and a dairy.

First, a survey was carried out in a process hall during packaging of salt fish, where samples were taken from different sites. After that, 12 wooden pallets and four plastic pallets (2 of each type) were placed in the salt fish warehouse, each loaded with 1000 kg of salt fish and then stored for two months. Samples were taken at the beginning and also after 2 months. This experiment was repeated once. At the dairy, where only plastic pallets (polyethylene) are normally used, a survey was carried out to get some

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information about plastic pallets used in this sector. At a distribution company for supermarkets four types of wooden pallets and two plastic pallets (3 of each kind) were tested. The pallets were distributed to various foodstores in Reykjavik. In this case, samples were taken from the pallets (0 point) and that was repeated when they were returned. The swabbing and the contact methods were used to evaluate the total bacterial and mould counts. Only results obtained from swabbing method are presented in this report.

2.1.3 Wooden pallets for production of salt fish.

Wooden pallets have traditionally been used in the production of salt fish but now it is forbidden to use wood in direct contact with food. The wooden pellets have therefore been replaced by plastic tubs made of polyethylene (Figure 3). For this experiment, new wooden pallets were made as shown in Figure 4. The wood pallets were made of spruce, plywood and steel and manufactured in Iceland. In co-operation with one of the producers of salt fish in Iceland, an experiment was carried over a one-year test period. Samples were taken after cleaning and after each process cycle. This was repeated 8 times. Icelandic authorities gave their permission for this study, although it is prohibited to use wood pallets in direct contact with the products during the processing of salt fish.

Figure 3. Plastic tubs used for the production of salt fish

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Figure 4. Wood pallets used for the production of salt fish

Processing of salt fish consists of brining for 1-2 days in palstic tubs, followed by curing for 10 days and storage for 10 days in wood pallets or plastic tubs. Plastic tubs were also studied for comparison. The cleaning procedure for the pallets started with rinsing them with lukewarm water and under high-pressure, followed by alkaline foaming for 20 minutes and soft brushing. After foaming, the pallets were rinsed again with lukewarm water and then left to dry for 1-2 days. The swabbing method was used to evaluate the total bacterial and mould counts.

2.2 Sampling

Swab samples were taken from each surface, which was to be evaluated for hygienic conditions. The swab samples were taken using hydrophobic cotton swabs wet in D/E neutralising broth (Difco) or Butterfield´s buffer (APHA, 1992). The swab was streaked over an area of 2x50 cm^2 and then placed and kept in a sterile, closed container. All samples were kept cold and analysed within 24 hours after being collected.

2.3 Microbiological analysis

The swabs were rinsed in 10 ml Butterfield´s buffer the rinsing solution diluted (1/10) further in the same buffer where needed. The following media and incubation conditions were used to enumerate microbial counts of samples with spread (surface) plate method: Plate Count Agar (PCA, Difco) supplemented with 0.5% NaCl (w/v) (APHA, 1992) for total bacteria at 22°C for 72 h; Potato Dextrose Agar (PDA, Difco) for yeast and mould at 22°C for 5 days (APHA, 1992) and Dussault Lachance Agar (DLA) for red halophilic

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bacteria at 37°C for 14 days (Dussault and Lachance, 1952). The detection limit for the swab method was 0.1 CFU (colony forming unit/cm^2). The contact method was also used in some of the experiments and then plates (24.6 cm^2) with D/E neutralising agar (Difco) were stamped on relevant surface. The contact plates were incubated for 72 h at 22°C.

2.4 Recovery of bacteria from gluelam and stainless steel - Laboratory tests

The samples were contaminated with *Pseudomonas* spp. which had been isolated in the fish industry to evaluate the recovery of the bacteria on gluelam with different treatments compared with that from galvanised steel. The bacterial suspension was grown over night at 22°C in brain heart infusion (BHI-Difco) and the initial level of the micro-organisms was 10^8 CFU/ml. A volume of 0.5 ml of dilution 10^{-1} was spread evenly on the sample. The contamination time was 2 hours at 20°C. The wood surface was 94 cm^2 and the surface of galvanised steel was 150 cm^2. The results are given in percentage of recovery. Bacteria were recovered from the surface of the tested samples according to the methods evaluated in the first partial report and regarded as suitable microbiological test methods for wood (Lorentzen et al. 2000).

2.5. Other analyses

Ambient temperature and relative humidity were measured with HOBO ProSeriec loggers for RH/Temp in each of the places where the tests were done. The moisture content in some samples was tested with moisture-o-meters (FMC moisture meter from AB Brookhuis Micro-Electronics in Netherland).

2.6. Statistical analysis

The statistical analysis was carried out with the Number Cruncher Statistical Software (NCSS) 2000, using analysis of variance, ANOVA and Two-Sample T Test. An effect was considered significant at the 5% level.

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3. RESULTS AND DISCUSSION

3.1 Wood in constructions - gluelam

3.1.1 Hygiene survey of wooden and steel surfaces in the fish industry

Hygiene surveys were performed at two defined sites in the fishing industry, in a processing hall and in a cold storage where salt fish is packed and stored. The fishing industry in Iceland still uses wood, mostly where it is in indirect contact with products. In these surveys, hygienic condition of different surfaces was evaluated. For hygiene evaluation, the IFL Guidelines (Table 1) were used but it has to be taken into account that these are meant for surfaces in direct contact with food. Guidelines for surfaces which are not in a direct contact with food are not available, but these kinds of guidelines should not be as stringent as those for surfaces in direct contact with food.

Table 1. Guidelines used at the IFL for cleaned surfaces that comes in direct contact with food

	swabbing-CFU*/cm^2	contact plate - CFU/plate	(* CFU = colony forming unit)
Very good	<1	0	
Good	1-4	1-10	ACCEPTABLE
Pour	5-50	11-100	
Very pour	>50	>100	UNACCEPTABLE

Table 2 shows the results from samples taken from surfaces in the packaging room during the production of salt fish. Based on the guidelines, the hygienic condition of the surfaces, which were tested, was unacceptable in all cases. The samples were taken when the plants were in operation so this is not a situation after cleaning. In this plant there was no standardised procedure for cleaning the wooden pallets and the same applies to many food processing plants. These results show that there is a need for a standardised cleaning procedure for the wooden pallets if they are going to be reused.

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Table 2. Hygiene survey in a process hall during packaging of salt fish

Sample sites	Swabbing CFU/cm^2 22°C	Contact -22°C CFU/plate
cold storage		
wood-pallet	860	>100
wood-pallet with load	1900	>100
steel	18000	>100
packaging room		
wood board	7400	>100
wood pallet 1	21000	>100
wood pallet 2	200	>100
wood pallet 3	1040	>100
plastic tub	1030	>100
steel box	1600	>100
plastic tub	74000	>100
plastic board	4000	>100

Table 3 shows the results from the samples taken from untreated gluelam and galvanised steel in constructions where salt fish is stored under cold conditions. These surfaces are not in a direct contact with the fish products, but the water which condensates on these surfaces can contaminate the product indirectly. Therefore, it is important that these surfaces are well maintained and cleaned. The surfaces, which were tested, had been in the building for 6-7 years. There was no difference observed between the results from gluelam and galvanised steel when compared by T-Test. A total of six samples (3 of each kind) were considered to be acceptable if in direct contact with food. The highest count was 125 CFU/cm^2 (2.1 $\log_{10}$ CFU/cm^2) from one sample taken off a steel surface. All other samples had numbers below 50 CFU/cm^2 (1.7 $\log_{10}$ CFU/cm^2), which can be considerd as good because these are not contact surfaces. The limit is <5 CFU/cm^2 for cleaned surface in direct contact with food.

Table 3*. Bacterial numbers(log_{10} CFU/cm^2) detected on construction material using swabbing method*

	No. samples	Mean ± SD	Min	Max	SE

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gluelam	11	0,71 ±0,92	0	1,68	0,28
galvanised steel	8	0,79 ±0,61	0	2,10	0,22

3.1.2 Laboratory study - bacterial recovery from gluelam

The results from the recovery tests are shown in Table 4. The highest recovery rate indicates that the microbes are more easily removed from a surface compared to samples from other surfaces with a lower recovery rate. If the micro-organisms cannot be easily removed with the methods used in this study, it can mean that the cleaning of the surface can be more difficult. If the recovery is low then the micro-organisms are most likely absorbed into the wood and there they can stay alive for some time, especially if the wood is wet. However, scientific studies in Germany have shown that when a comparison was made on the survival of *E. coli* on different wood species and PE, the number of *E. coli* decreased faster on the wood than on PE. The best effect was achieved on pine. The number of bacteria not only decreased on the surface but also to the same extent within the wood itself. (Schönwalder et al, 2000). Gluelam sample of type 1B is considered to be the most hygienic, because of the high recovery compared to the others. That sample was treated twice with a water based epoxy painting. The recovery from 1B differed significantly ($p<0,05$) from all others by analysis of variance. No difference was observed between other samples. The prevalence of bacteria within the wood was not evaluated in this study.

*Table 4. Recovery (%) of bacteria from constructions samples tested in duplicate (*nd=not detected)*

Series	Mean recovery (%)	Range (%)
Untreated gluelam	0,01	0,01-0,01
1A - Kopal primer (water based) and 2x Kopal acrylic paint.)	0,12	0,10-0,13
1B - 2x Kopal epoxy painting (water based)	1,14	1,07-1,21
2A -2 x Parquet painting (water based)	0,02	0,02-0,03
3B - 2x Epoxy painting (oil based)	nd*	
4A - 2x Kjörvari 14 (decay preservation - surface treatment	0,26	0,09-0,40
Galvanised steel	0,20	0,1-0,3

3.1.3 Microbiological surveys on differently treated gluelam samples

When reviewing the scientific literature (Lauzon, 1998) no information emerged where wooden surfaces, not in direct contact with food, could be identified as a hazard, creating

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a health risk. This study aimed at determining the hygienic properties of differently treated gluelam and galvanised steel used as a construction material in the food industry. The experiments were carried out under three different conditions. First in a warehouse for salt fish where the ambient temperature was low (-1,5 to +3°C) and the relative humidity was high (>80%); secondly in a processing hall where caviar is produced (high temperature about 16°C and high humidity, 60-80%); and finally where samples were moved every 4th day over a period of one month between different places with both high and low temperatures (0 and 15°C) and high and low relative humidity (20 and 80%).

The results from samples taken at the warehouse for the salt fish are shown in Figures 5 and 6. The survey went on for 16 months. The ambient temperature ranged from -1,5 to 3°C and the relative humidity in the air was more than 80% as seen in Figure 7. These conditions can influence the growth of the bacteria. The results can be considered as good where the total counts of the gluelam samples were below 5CFU/cm^2 for the first 10 months up to November. The counts of moulds and yeasts were below 1CFU/cm^2 during the time of the survey. The untreated control samples showed however higher numbers compared to treated samples. On the other hand, galvanised steel samples had the lowest numbers over the whole period. Nevertheless, it should be pointed out that the counts obtained for all wooden samples were very low. One should bear in mind, however, that these wooden surfaces were not in direct contact with food.

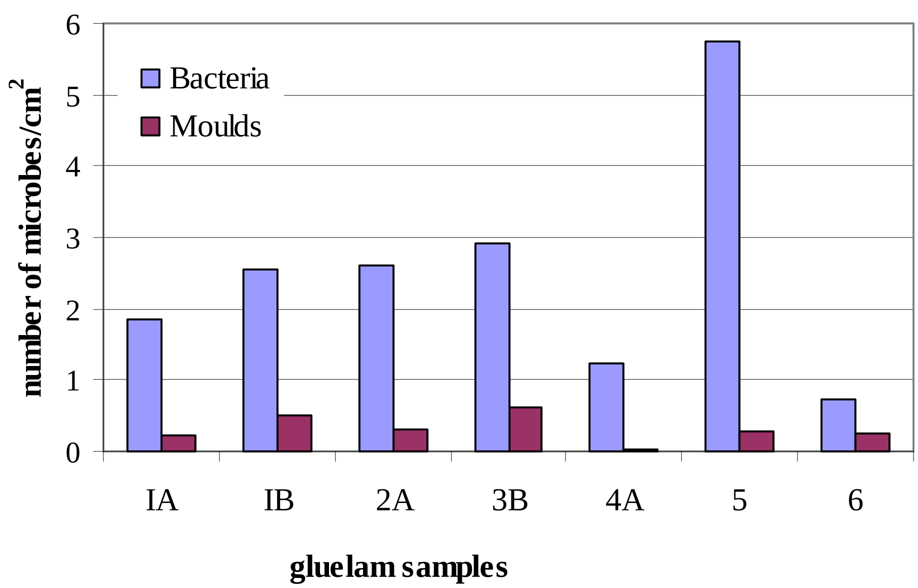

Figure 5. Number of microbes (average number from 8 sampling times) on differently treated gluelam and

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galvanised steel over a 16-month period in a wet and cold environment at a warehouse for salt fish (-1.5 to +3°C and >80% RH). 1A is treated once with Kopal primer (water based) and twice with Kopal acrylic painting (water based); 1B: twice with Kopal epoxy painting (water based); 2A: twice with Parquet painting (water based); 3B: twice with Epoxy painting (oil based); 4A: twice with Kjörvari 14 (decay preservative - surface treatment); 5: untreated gluelam and 6: galvanised steel.

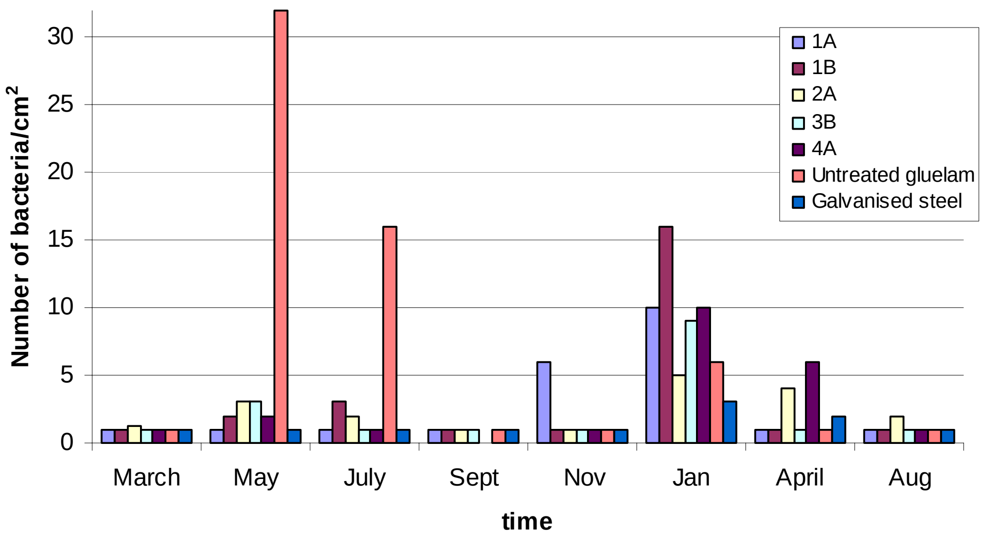

Figure 6. Number of bacteria on gluelam samples and galvanised steel in a wet and cold environment at a warehouse for salt fish (-1.5 to 3°C and >80% RH) in relation with time. 1A is treated once with Kopal primer (water based) and twice with Kopal acrylic painting (water based); 1B: twice with Kopal epoxy painting (water based); 2A: twice with Parquet painting (water based); 3B: twice with Epoxy painting (oil based); 4A: twice with Kjörvari 14 (decay preservative - surface treatment); 5: untreated gluelam and 6: galvanised steel.

Figure 7 shows an example of the results from an online recorder, which measures temperature and relative humidity in a warehouse for salt fish over a 6-month period. The temperature was very low, most of the time below 0°C, but occasionally the temperature would increase and the highest temperature reached was 3.5°C which is still very low and sufficient to delay the growth of some micro-organisms. On the other hand, the relative humidity was high and could stimulate the growth of micro-organisms. Therefore, in order to use wood in the food industry there are some aspects to consider. For different sectors with exposure to various types of bacteria different solutions could be needed. Different treatments of the gluelam may be necessary for different hygienic requirements.

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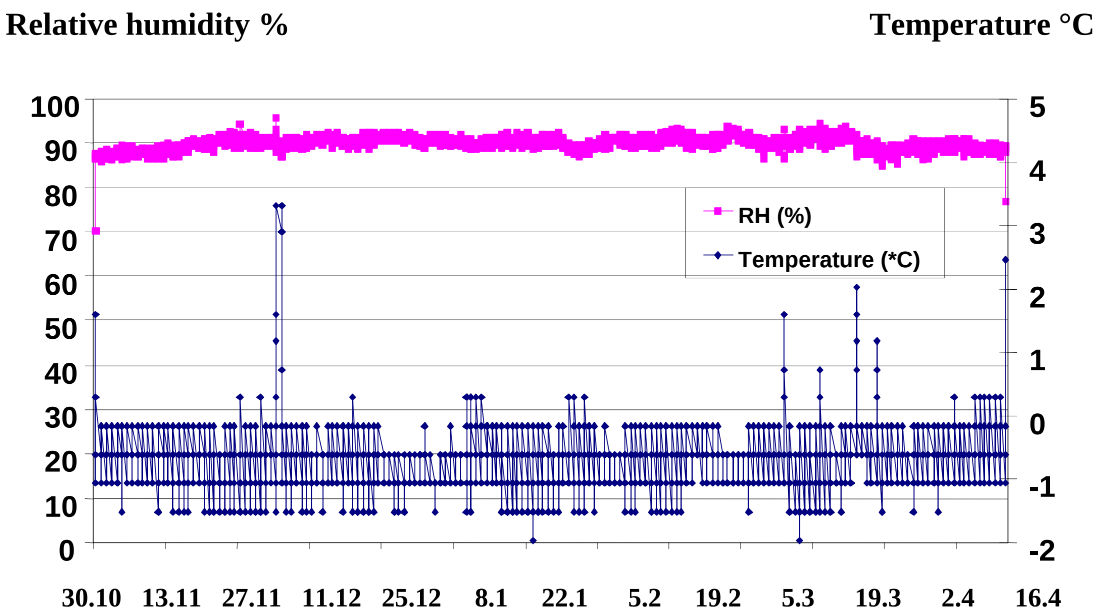

Figure 7. Temperature and relative humidity in a warehouse for salt fish over a 6-month period

Figure 8 and shows the number of bacteria and moulds in samples taken from gluelam which were stored in a caviar processing factory over a 10-month period where the ambient temperature was 16-18°C and the relative humidity 60-80%. These results are similar to the results obtained from samples taken in the warehouse for salt fish. Still the counts are very low and even lower under these conditions compared to the salt fish warehouse (Figure 5). It is interesting to see that the number of micro-organisms detected on samples marked 4A, which was treated with decay preservative, was lower compared to the number detected on other gluelam samples in both cases (Figures 5 and 8). The overall results can be considered as good where the total counts of the gluelam samples were below 5CFU/cm^2 and the counts of moulds and yeasts were below 1CFU/cm^2 while the survey was conducted over a 10-month period. The untreated control samples again showed higher numbers compared to the treated samples.

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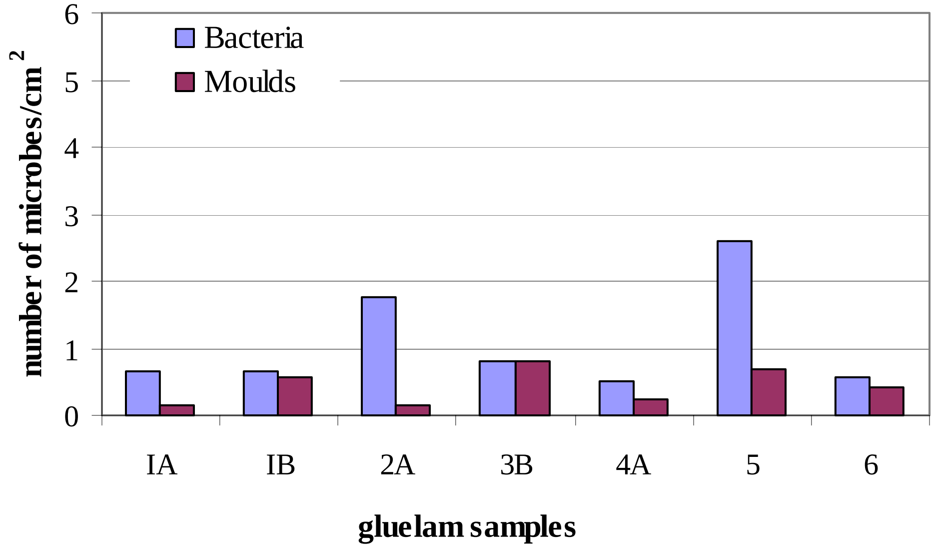

Figure 8. Number of micro-organisms (average number from 2 sampling times) on differently treated gluelam in caviar processing factory over a 10-month period. The temperature was 16-18°C and the relative humidity 60-80%. 1A is treated once with Kopal primer (water based) and twice with Kopal acrylic painting (water based); 1B: twice with Kopal epoxy painting (water based); 2A: twice with Parquet painting (water based); 3B: twice with Epoxy painting (oil based); 4A: twice with Kjörvari 14 (decay preservative - surface treatment); 5: untreated gluelam and 6: galvanised steel.

Another study was done at the IFL where gluelam samples were stored at 0°C and 15°C over a period of one month in two different working rooms. Every 4th day the samples were moved between the rooms and the ambient temperature and humidity were measured, as shown in Figure 9. The results from the microbiological tests are shown in Figure 10. When moved between different climatic conditions the microbes are more easily attached to the surfaces but still the number of microbes detected on the different samples did not differ significantly ($p>0,05$) except that the untreated gluelam samples differed significantly from the others ($p<0,05$). During the last week some kind of a disturbance did affect the temperature and the humidity in the working room as shown in Figure 9.

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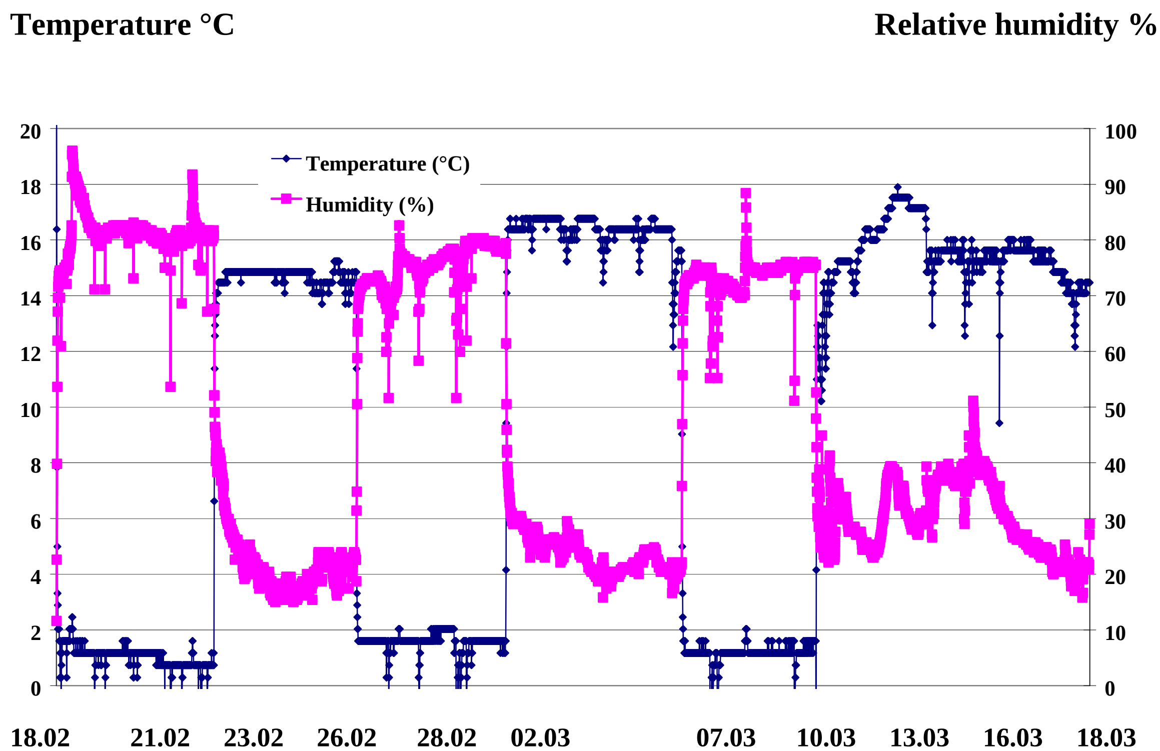

Figure 9. Temperature and relative humidity when construction samples were moved between different climatic conditions over a 1-month period

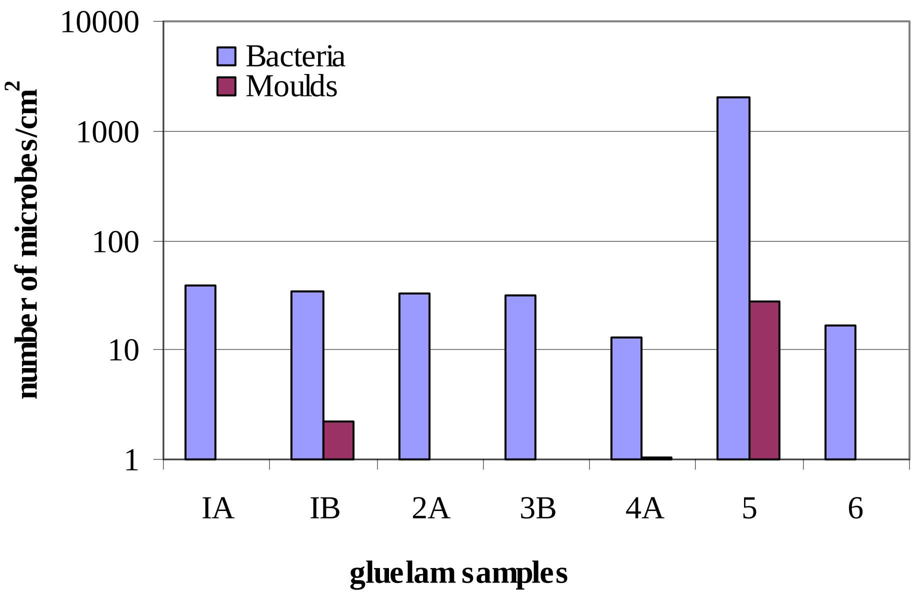

Figure 10. Number of micro-organisms on differently treated gluelam moving between different climatic conditions. 1A is treated once with Kopal primer (water based) and twice with Kopal acrylic painting (water based);1B: twice with Kopal epoxy painting (water based); 2A: twice with Parquet painting (water based); 3B: twice with Epoxy painting (oil based); 4A: twice with Kjörvari 14 (decay preservative - surface treatment); 5: untreated gluelam and 6: galvanised steel.

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When evaluating the overall results from these three gluelam experiments the lowest microbial counts were found on the surface 4A which was treated twice with a decay prevention (surface treatment). The highest counts were found on untreated gluelam samples which were used as a control (Figures 5,8 and 10). Microbial counts detected from the differently treated gluelam and galvanised steel were generally not statistically different ($p>0,05$) when stored under the same conditions but gluelam treated with decay prevention and galvanised steel differed significantly from the untreated samples ($p<0,05$). The results indicates a significant difference in microbial counts between different conditions after 10 months in use but this difference is expected to decrease over a longer time period (data not shown).

Samples, which were moved between different locations with different climatic conditions, had the highest number of micro-organisms (Figure 10). The lowest number of micro-organisms was detected on samples which were kept in a warm (16-18°C) and humid (60-80%) environment (Figure 8). From these results it can be concluded that gluelam is as good as galvanised steel as far as hygienic properties are concerned and the use of such wood is relevant in constructions. This knowledge can be transferred to other conditions, those in frozen and cold storage in the food industry. This study supports the conclusion made by Worfel et al. (1995) that material used in construction of food production plants is not as important as other factors, like avoiding the condensates, and that good cleaning is essential for all types of material. Individual results are shown in Appendix I-III.

3.2 Wooden pallets for storage and transportation

Industrial packaging material and pallets made of wood play an important role in the distribution chain of food products. There is an increasing pressure on manufacturers to use food packaging material that is environmentally friendly, not only in its usage and its disposal but also with regard to its source and production. The forest is a good source for wood and is easy to maintain and it is important to underline that wood is made of a renewable resource from a sustainable forestry. The annual growth is exceeding the

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harvest. Therefore, if the environmental aspects are considered, pallets made of wood are more environmentally friendly than plastic pallets. This study compared six different types of wooden pallets and two types of plastic pallets used for storing and transporting salt fish, goods for supermarkets and dairy products. The initial moisture content in the pallets was 10-15% water but after two months the difference in hygienic conditions between the wooden and plastic pallets was negligible when determined by analysis of variance (p>0,05).

3.2.1 Hygiene survey on pallets used in a dairy

The results from the hygiene survey in a dairy are shown in Figure 11. The hygienic condition of the pallets was not good. Fourteen samples were taken from plastic pallets, made of polyethylene (9 cleaned and 5 uncleaned pallets). These pallets were already in use in this distribution chain and therefore not new. The pallets were tested both cleaned and uncleaned. The total bacterial and mould counts were evaluated by the swabbing method. The cleaning methods used were not well defined and the pallets were only cleaned occasionally and then just rinsed with water.

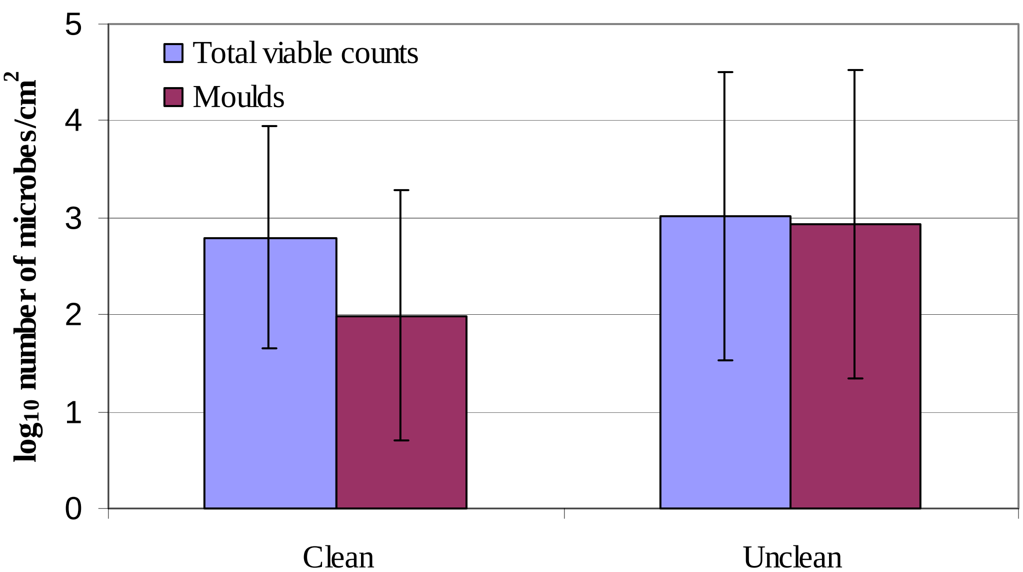

Figure 11. Results from the hygiene survey on plastic pallets used in a dairy. Mean values and standard deviation (bars).

Even after cleaning, the pallets were considered unacceptable for use in direct contact

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with food, based on the IFL guidelines. The high number of micro-organisms indicateed that the cleaning method that was used was not efficient - not even for items in indirect contact with food. A T-Test did not reveal any differences between cleaned and uncleaned pallets. Individual results are shown in Appendix IV.

3.2.2 Hygiene survey on pallets in a distribution chain for supermarkets

Of seventeen pallets which were distributed to a supermarket chain, only seven pallets were regained after 2 months. Therefore, all of the wooden pallets were evaluated as one group, compared to the two types of plastic pallets, PE and HD-PE. The temperature was about 16°C and the relative humidity 25-30 % RH. The results are shown in Figure 12.

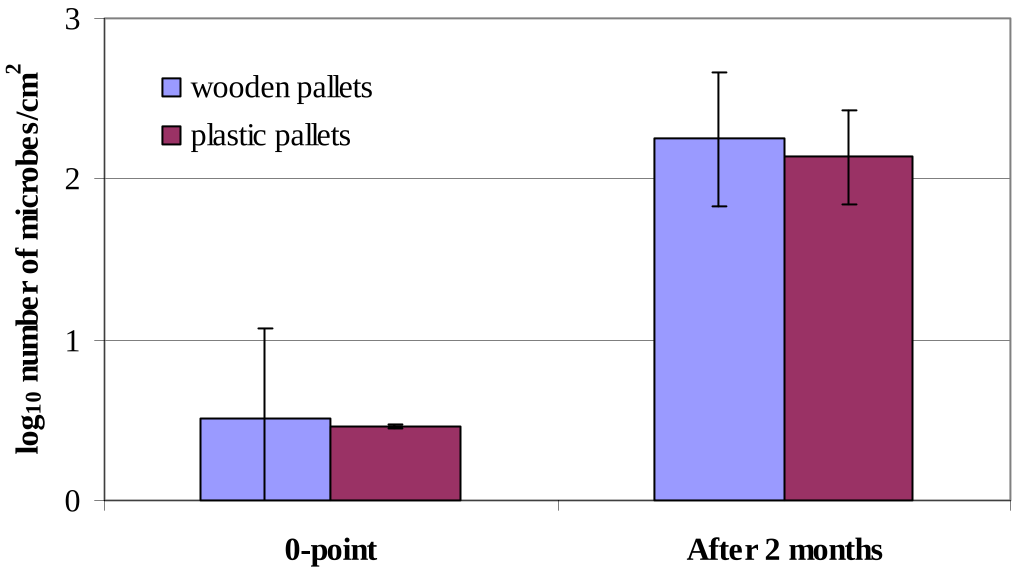

Figure 12. Number of microbes on wooden pallets (4 types) and plastic pallets (2 types). Mean values and standard deviation (bars) in a warm (16-18°C) and dry environment (25-30 % RH)

When the results which are presented in Figure 12 are compared with Figure 11, one can see that the number of bacteria on wooden and plastic pallets after two months in a dry and warm environment and without cleaning are almost the same as that on the plastic pallets after cleaning at the dairy. No statistical evaluation was carried out on these

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results because of the missing pallets. Individual results results are shown in Appendix V.

3.2.3 Hygiene survey on pallets used in a salt fish storage

Six different types of wooden pallets and two types of plastic pallets were examined over period of one-year in a salt fish warehouse. Figure 13 shows the average results when the wooden pallets are compared with the plastic pallets, without taking into account different types of plastic or wood pallets.

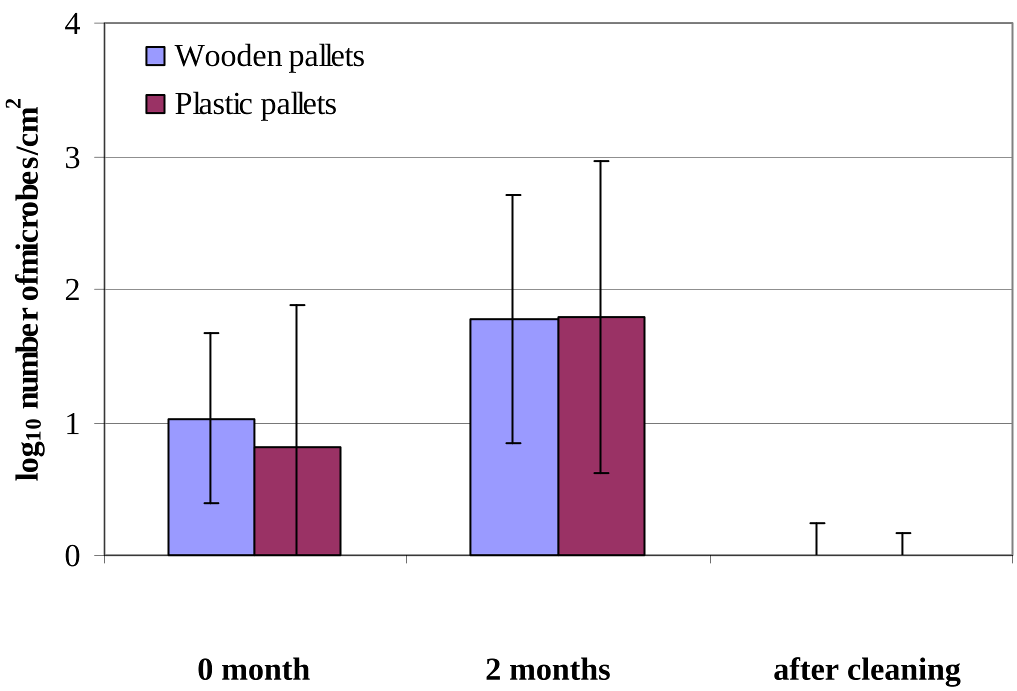

Figure 13. Number of microbesa on wooden pallets (6 types) and plastic pallets (2 types). Mean values and standard deviation from two surveys after 2 months in wet (>80% RH) and cold (<3°C) environment and after cleaning with high-pressure cold water

The reason for the bacterial contamination detected in the beginning could be that the pallets were not cleaned after they had been stored for some time before the experiment started. The storage conditions were not controlled. After two months of use in the salt fish warehouse where 1000 kg of salt fish were stored on each pallet, an increase in number of micro-organisms was observed and found to be quite similar on wooden and plastic pallets. There was no significant difference detected between the wooden pallets

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and the plastic pallets before and after cleaning with high-pressure (180 kg/cm^2) cold water. Figure 14 shows the results for individual pallet types after two-months storage time and after high-pressure cold water cleaning. Samples taken from pallets made of HT-spruce, pine and PE had the lowest number of micro-organisms after a two-months storage period in a wet and cold environment but the difference compared to other types did not differ significantly.

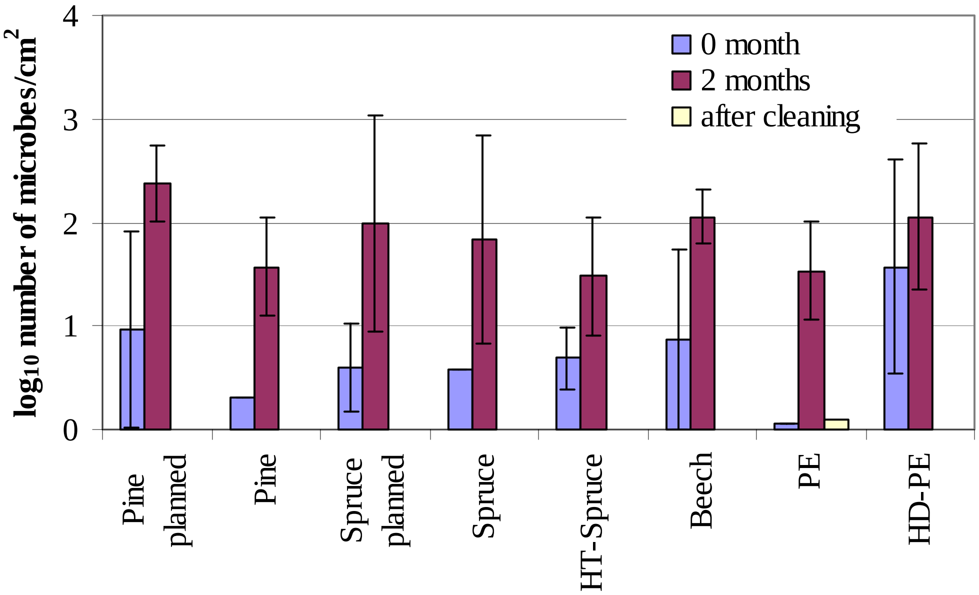

Figure 14. Number of microbes on wooden pallets (pine, spruce, beech) and plastic pallets (PE, HD-PE) after use for 2 months in wet (>80% RH) and cold (<3°C) environment in a salt fish warehouse and after cleaning with high-pressure cold water. Means from two surveys and standard deviation (bars).

The cleaning efficiency was evaluated and was found to be very good for all types of pallets tested. No chemicals were used during cleaning. No red halophilic bacteria were detected in the samples taken from the pallets stored in the salt fish warehouse.

This research does not make a judgement about the hygienic qualities of wooden pallets on the one hand and plastic pallets on the other. But when choosing the right material the quality and the type of wood used in the pallets have to be considered. However, the low ambient temperature and the high salt concentration on the pallets used during salt fish storage can prevent the growth of bacteria as well as the dry conditions in the distribution chain for supermarkets. These findings can surely not be extrapolated to all other environments, where e.g. humid and wet conditions do occur. An environment with a

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high ambient temperature and a high relative humidity can favour the growth of micro-organisms and therefore untreated wooden pallets should not be used under these conditions. Various treatments which aim to prevent water absorption and make the wood water-repellent are therefore of interest. One effective way make the wood water-repellent is to treat the timber with a wax emulsion, which is a fairly simple and inexpensive method. Previous studies have shown that water absorption can be reduced by 40-60% (Beyer and Guðbjörnsdóttir, 2000). Only clean and dry pallets should be used in the food industry. Cheap pallets, made of mixed types of wood, are commonly used in the food industry but they are not of high quality and not good where hygienic quality is required. It is very important that the user of wooden pallets, as well as of pallets made of other material, set some standards and requirements for the pallets they are buying and that they refuse to accept just any pallets that do not fulfill their requirements. The requirements for the quality can vary, depending on the different uses intended, e.g. the boards can be planed and if the pallets are dirty the pallets need to be cleaned and dried before they are reused. Studies have shown that cleaning the pallets with cold water under high pressure, with an additional drying step, gives a very good and acceptable results. However, the use of high-pressure involves the formation of fine droplets of water, which hit the surface to be cleaned at the chosen high-pressure and then diffuse in the air. This raises humidity, which in turn encourages the multiplication of micro-organisms on walls, ceilings, etc. This can be prevented by using a cleaning hood, for example where the pallets pass through. A good alternative can be to use e.g. floor cleaners with appropriate attachment when cleaning wooden pallets. Individual results are shown in Appendix VI.

3.3 Wooden pallets in the production of salt fish.

Pallets made of wood have been used for many years in the processing of salt fish but now their use is not permitted any longer. Instead, plastic tubs made of polyethylene are used. This change is mainly because of modifications brought on by different regulations. Cross-contamination is a main concern because wood is a porous and absorbent material where organic matters, along with bacteria, can become entrapped. Sanitation of surfaces in contact with food is absolutely vital in the food industry because such surfaces can

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cause microbiological contamination in the food products. Some bacteria have the tendency to adhere to hard surfaces, multiply and produce extracellular polymeric substances, forming a so-called biofilm (Lauzon, 1998). In this study, the hygienic conditions and the use of wooden pallets and plastic tubs during the production of salt fish was compared as well as the efficiency of the cleaning methods. Previous studies have shown that satisfactory hygienic conditions for surfaces in direct contact with food can only be ensured with daily cleaning and disinfection (Abrisham et al, 1994, Krysinski et al, 1992, Miller et al,1998). Figure 15 shows the distribution of bacteria on wooden pallets and plastic tubs after cleaning with high-pressure/warm water/alkaline foaming and after the salt fish had been processed. It takes about 20 days to produce salt fish. The results indicate that the cleaning procedure is not efficient and has to be reconsidered.

All samples (both taken from wooden pallets and plastic tubs) were unacceptable when compared to the guidelines used at IFL as shown in Table 1.

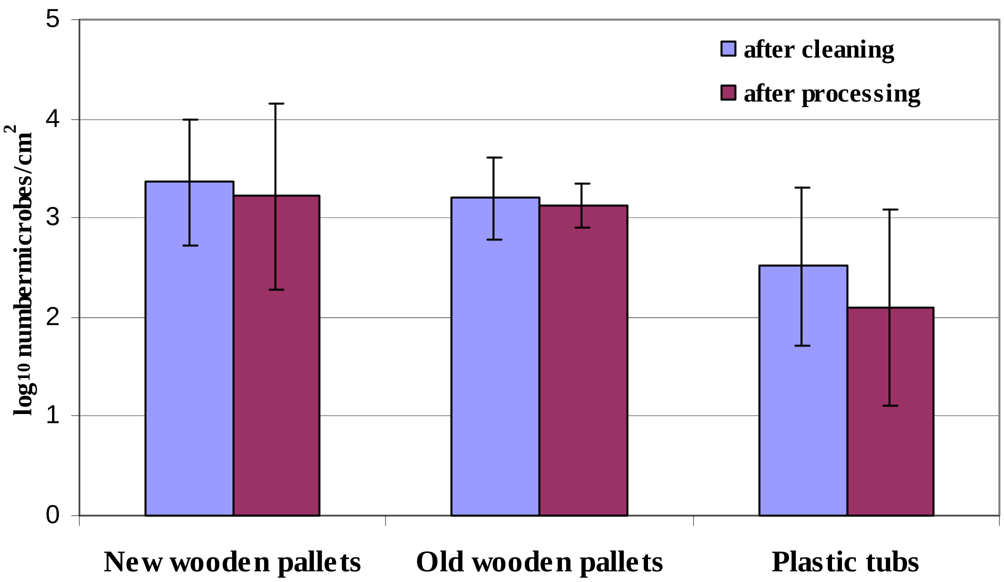

Figure 15. Number of bacteria on wooden pallets and plastic tubs after cleaning and after processing. Mean from 8 surveys.

It is interesting to notice that after the process had been going on for 20 days, the number of bacteria decreased, especially in the plastic tubs. One reason may be the effect of the high concentration of salt, which many bacteria cannot tolerate, but the bacteria could

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also have been rinsed off with the brine. During cleaning, the salt is easily removed, but other dirt can remain on the pallets which could lead to bacterial growth prior to use. It has been shown that *E. coli* and *Staphylococcus aureus* can survive for many weeks in salt fish (Huss and Valdimarsson, 1990 and Magnússon and Guðbjörnsdóttir, 1989). Therefore, hygiene is very important in the production of salt fish. The plastic tubes are apparently easier to clean and in this case more hygienic. The number of microbes detected on plastic tubs differed significantly from the number detected on wooden pallets but still the cleaning efficiency was not good enough. No significant differences were observed on wooden pallets whether they were new or old. The cleaning method could possibly be improved with additional steps, involving the use of a nylon brush and intensive scrubbing.

4. CONCLUSIONS

The main conclusion derived from these studies is that the wooden pallets which were tested are as good as the plastic pallets tested and that the gluelam is as good as the galvanised steel used in construction. However, it has to be taken into account that different types and different treatments of the pallets and gluelam may be necessary for different hygienic requirements. Wood is not just wood, there are many different types of wood and it should be handled with care, e.g. wooden pallets should never be stored unprotected outdoors in order to avoid biological, physical and chemical contamination. In fact, the same also applies to plastic tubs and plastic pallets. Information about HACCP, GMP, guidelines for handling, cleaning and sanitation of wooden pallets are given in report 8 (Beyer and Guðbjörnsdóttir, 2002).

The main thing to remember is that there probably does not exist any one material which is best suited for all contact surfaces, one needs to evaluate each situation independently and then make a decision about the choice of material accordingly. One must however always bear in mind which standards or regulations regarding this matter are in place in each country.

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APPENDIX I.
Number of micro-organisms on different treated gluelam and galvanised steel in salt fish warehouse.
Ambient temperature -1,5-3°C

Number of micro-organisms (CFU) /cm^2							
Gluelam samples							
Time (month)	IA	IB	2A	3B	4A	CONTROL	STEEL
0	1,6	0,1	3,8	0	1,8	0,1	0
0	2	0,1	2,4	2	0,1	0,1	0,9
2	0	0,6	4,7	0	0	0,1	0
2	0,7		1,8	3	0,1	2,4	0,1
2	0,1	0,2	4,2	0,2	0,2	0,1	0,2
2	0,4	4	2	6	3	71	0,2
4	1,4	0,1	22,6	4,4	0,2	20,6	3,2
4	2	2,8	1,4	14	0,2	1,8	1
4	0,8	2	0,1	0	0	10,2	0,2
4	0,4	4	2,8	1,6	1,6	21,2	0,6
4	1,4	1	1,6	1,2	0,4	2,8	0
4	0	1,6	1,6	1,6	0	2	0
6	1,5	6	4,1		0,9	1,2	5,3
6	0,2	3	0,7	1,3		0,5	0,1
6	0,1	2,1	0,1	1,4	0	0,4	0
8	1,2	4,4	0,2	0,4	0,1	1,9	0
8	6,2	0,8	0,2	0,2	0,2	0,2	1,4
8	0	0	0,3	0,2	0	0	0
10	4,3	0,2	0,1	0,5	0,1	0,2	0
10	2	1	3	0,1	0	0	0,2
10	10	16	5	9	10	6	3
13	2,4	1,7	0,3	1,3	0	2,8	1,7
13	1,9	0	0,6	7	1	5,5	0,5
13	0,2	8,2	0,8	2,6	0,1	1,5	0,2
16	8,5		0,7	15	12	0,1	0
16	0,3	0,2	2,4	0,7	0	0,5	0
16	0,1	3,5	3	2,2	0	2	0,6

Numberof moulds and yeasts (CFU) /cm^2							
Gluelam samples							
Time (month)	IA	IB	2A	3B	4A	CONTROL	STEEL
4	0,2	0	0	5	0	0,3	0,2
4	0,3	1,4	0,3	1	0	0	1
4	0	0	0	0	0	0	0,2
4	0,4	0,1	2	0,8	0	3	0,8
4	0	0,4	0,6	1	0,2	0	0
4	0	0,4	0,2	0	0	0,4	0
6	0,6	0,9	0,9		0	0,5	0,6
6	0	0,9	0	0,2		0,2	0
6	0	0,3	0,4	0,3	0	0	0
8	0	1,2	0,3	0,3	0	0	0
8	0	0,1	0,2	0,2	0	0,2	0
8	0	0	0	0	0	0	0
10	0	0,1	0,3	0,1	0	0,2	0
10	0	0,1	0	0	0	0	0
10	3,1	3,1	1,1	1,2	0,3	0,2	2,5
13	0,2	0,6	0	0,1	0	0,1	0
13	0	0,3	0	0	0	0,4	0
13	0	0,4	0	0	0	0,1	0
16	0	0,1	0	1,6	0,3	0	0
16	0	0	0,2	0,2	0	0	0
16	0	0,4	0	0,5	0	0,2	0

APPENDIX II

Number of micro-organisms on different treated gluelam and galvanised steel in a caviar processing factory. Ambient temperature 16-18°C

		Number of micro-organisms (CFU)/cm^2						
		Gluelam samples						
	Time (month)	IA	IB	2A	3B	4A	CONTROL	STEEL
total viable counts	4	0,1	0,5	0,9	0,6	0	12	0,3
total viable counts	4	0,1	0,3	0	0,2	0,6	0,4	0,1
moulds and yeasts	4	0,3	0,3	0,4	0,3	0	0	0
moulds and yeasts	4	0,3	0	0,2	0,1	0,4	0,3	0
total viable counts	10	0,2	1,5	0,9	0,7	0,4	0,7	2
total viable counts	10	0	1,5	2,6	1,3	0,1	2,2	0,1
moulds and yeasts	10	0	1	0	1,2	0,2	0,7	1,7
moulds and yeasts	10	0	1	0	1,6	0,3	1,7	0

APPENDIX III

Number of micro-organisms on differently treated gluelam moving between different climatiic conditions

			Number of micro-organisms (CFU)/cm²						
			Gluelam samples						
Temperature (°C)		Time (weeks)	IA	IB	2A	3B	4A	CONTROL	STEEL
20	total viable counts	0	3	11,1	3,7	4	0,8	1,3	3,6
20	total viable counts	0	120	155	109	102	3	14	26
20	moulds and yeasts	0	0	1,5	2,2	6	1,1	0,8	0,5
20	moulds and yeasts	0	0,7	8	5,9	0	2,2	0,2	0,3
0	total viable counts	2	4,5	1,8	4,6	4,2	13,7	540	51
0	total viable counts	2	50	9	31	56	22	11000	1,1
0	moulds and yeasts	2	0,1	0,1	0,7	0,5	0,7	10	0,2
0	moulds and yeasts	2	0,4	0,2	0,3	0,4	0,2	152	0,2
20	total viable counts	4	32	28	23,8	11	20	57	4,6
20	total viable counts	4	19	3	28	10,3	18	660	15
20	moulds and yeasts	4	1,3	3,1	0,1	0,9	1,4	2	0,1
20	moulds and yeasts	4	0,5	0,4	0,3	0,4	0,7	1,3	0,2

APPENDIX IV
Number of micro-organisms on pallets used in dairy.
Ambient temperature 0-18°C and humidity 25-30% RH

	Number micro-organisms CFU/cm^2	*Number moulds and yeasts CFU/cm^2*
Cleaned pallets	570	3,2
Cleaned pallets	37000	330
Cleaned pallets	35	10
Cleaned pallets	38	13
Cleaned pallets	540	300
Cleaned pallets	38	6
Cleaned pallets	10500	10000
Cleaned pallets	270	59
Cleaned pallets	8300	6000
Uncleaned pallet	17700	8500
Uncleaned pallet	9300	9300
Uncleaned pallet	10600	6000
Uncleaned pallet	48	34
Uncleaned pallet	13	4

APPENDIX V

Number of micro-organisms on pallets in a distribution chain for supermarket.
Ambient temperature 16-18°C and humidity 25-30% RH

	Number micro-organisms (CFU) /cm²	
Pallets	**0-point**	**2 month**
Pine	4	
Pine	2	
Pine	2	
Pine-planed	1	
Pine-planed	1	
Pine-planed	1	170
Spruce-planed	1	
Spruce-planed	1	180
Spruce-planed	11	180
Spruce	36	
Spruce	35	
Spruce	2	
HD-PE	1	68
HD-PE	7	
HD-PE	6	240
PE		85
PE	1	250
Old wooden pallets		750
Old wooden pallets		760

APPENDIX V1

Number of micro-organisms on pallets used in salt fish storage
Ambient temperature -1,5-3°C °C and humidity >80% RH

		Number micro-organisms (CFU) /cm²	
Pallets	*Time in use (month)*	*Before cleaning*	*After cleaning*
Pine planed	0	2	
Pine planed	0	43	
Pine planed	2	92	0
Pine planed	2	490	0
Pine planed	2	300	0
Pine	0	2	
Pine	0	2	
Pine	2	92	0
Pine	2	11	1
Pine	2	52	
Spruce	0	36	
Spruce	0	4	
Spruce	2	67	0
Spruce	2	1	1
Spruce	2	43	
Spruce-planed	0	12	
Spruce-planed	0	48	
Spruce-planed	2	33	1
Spruce-planed	2	19	56
Spruce-planed	2	1550	0
Beech	0	11	
Beech	0	5	
Beech	2	243	0
Beech	2	79	0
Beech	2	63	1
Beech	2	134	0
HT-spruce	0	8	
HT-spruce	0	3	
HT-spruce	2	35	0
HT-spruce	2	118	0
HT-spruce	2	5	0
HT-spruce	2	41	
PE	0	1	
PE	0	1	
PE	2	2	3
PE	2	1	1
PE	2	2500	1
PE	2	210	1
HD-PE	0	200	
HD-PE	0	7	
HD-PE	2	14	0
HD-PE	2	83	0
HD-PE	2	630	0
HD-PE	2	220	0

APPENDIX VII

Number of micro-organisms on pallets used during salt fish production

Total viable count (CFU/cm²)		
New wooden pallets	**Old wooden pallets**	**Plastic tubs**
1673	8230	1568
25018	12200	371
25032	13500	215
29033	6325	3
2085	788	4
1895	1013	126
205	416	13
2145	359	1723
698	1770	1178
2365	181	18
2080	556	23
1735	2035	13
1093	1863	683
2723	531	185
774	398	830
620	1123	731
2663	71	117
2033	1728	198
204	406	10675
183	222	91
89	581	6
1027	2920	
10545	21	
1025	3331	