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Hygienic acceptance of wood in food industry

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Abstract Food is physically manipulated by other materials during production processes, and therefore, food quality and safety are vital in processes where foods are in contact with various materials. Wooden frames were used for centuries for dried egg pasta trays; however, with the development of different materials, wood was slowly abandoned and replaced by plastic. Nevertheless, there are some hygienic considerations concerning plastic frames in the dried egg pasta making industry. In this study, plastic and wooden trays were analysed by swabbing ($n = 210$) and evaluated in regard to total number of aerobic counts (TAC), Enterobacteriaceae, *Escherichia coli*, moulds, yeasts and *Staphylococcus aureus* using dry medium plates. The aims of the research were to (1) evaluate the total number of microorganisms on wood and plastic material used for pasta trays and (2) make a hygienic evaluation of analysed materials for application in the pasta industry. The research was aimed to answer the question, 'Does the tray material and/or location of the swab sample influence the colony forming unit (CFU)/20 cm^2?' Results showed a statistical difference in CFU/20 cm^2 for all bacterial determinations, except for *E. coli* which was not detected in swabs taken from wooden or plastic trays. This hygiene evaluation study supported the conclusion that the use of wood is appropriate in the food industry from a hygienic and technological point of view.

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Introduction

The food processing system involves a complex, concentrated and dynamic chain of activities beginning with the production of raw agricultural commodities on farms, orchards and ranches and then moving from value-added processes to manufactured products and then to retail food stores and food service establishments where they are merchandized, prepared and sold to consumers (Tansey 2008). 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 (Marriott and Gravani 2006; Burlingame and Pineiro 2007). Today, food safety is managed 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 (Raspor and Jevšnik 2008; Jacob et al. 2010).

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 (Untermann 1998; Paster 2006; Wirtanen 2007). Failure during food processing, especially time and temperature abuse, may allow survival and proliferation of pathogenic bacteria, moulds and the production of toxins (Gough and Dodd 1998; Pohar 2002; Raspor 2002; Steenstrup 2007). To prevent adverse effects on health, it is important that every link in the food supply chain understands the importance of good hygiene practice, good manufacturing practice and the hazard analysis critical control point (HACCP) system. Surface sampling is a tool for hygiene evaluation and provides an indicator of contamination sources (De Smedt 1998; Dežman 2000; DIN 10113-1:1997a, 10113-2:1997b; Holah 2003; James et al. 2005; Salo and Laine 2000). It is also an effective method in the HACCP verification process for the internal control of hygiene. When choosing a suitable method for the detection of microorganisms, it is important to know what kind of information is needed. It is also important to figure out the breadth of sampling, the amount of samples and the frequency of sampling when choosing the method (Lorentzen and Guðbjörnsdóttir 2000; Salo et al. 2007).

In the past, wood was used as a traditional material for many applications in the food industry. Wood is presently being used in many areas such as those involving utensils, interiors, buildings, as well as in pallets and packaging. Hygienic and functional acceptance of wood in food industry and households depends on many factors like quality, type and treatment of wood. The microorganisms could proceed more deeply in transversal cuttings (more than 4 mm deep) than in wood being cut in longitudinal way as reported by Prechter et al. (2002). Some studies (Schönwälder et al. 2000; Worfel et al. 1995) on the hygienic properties of wood confirm that wood is as good as other materials for the use in the food industry (Beyer and Guðbjörnsdóttir 2002; Lauzon 1998). In the food industry involving dried egg pasta (e.g. spaghetti, elbow macaroni, screw-shaped pasta, spirals, butterflies, shells, ribbons, etc.), wooden trays are used for drying the fresh pasta. Since only a surface of wooden parts of trays is in direct contact with the pasta, the method of evaluation of surface microorganisms represents objective and comparative results. Wood was traditionally used during these drying processes, especially

oak. However, with the development of other materials, particularly PET (polyethylene terephthalate) materials, wood was gradually replaced. The most difficult and expensive stage in the manufacture of pasta products is the drying process (Dalbon et al. 1996; De Zorui et al. 2007; Pollini 1996). The drying of egg pasta is a preservation process and can be considered a critical control point. The aim of drying is to reduce the content of water to below 13.5% according to National Gazette No.26/2003, page 3266. Since the migration of water from internal to external layers, and so to the surface, takes place by capillarity, the pasta must maintain an appropriate structure (porosity) in relation to its current moisture as required by regulation (De Temmerman et al. 2008; Johnston 2001; McNabb and Anderssen 2007). Enterobacteriaceae are gram-negative facultative anaerobic rods represented by *Escherichia*, *Citrobacter*, *Salmonella*, *Shigella*, *Klebsiella*, *Enterobacter*, *Serratia*, *Proteus*, *Yersinia*, *Erwinia*, and others. *E. coli* is gram-negative and is generally a harmless part of the normal microflora of the gut of humans and other warm-blooded animals. Groups of *E. coli* are pathogenic for humans and are associated with food-borne disease. A few moulds, and possibly yeasts, can grow in that range, whereas bacteria only grow at somewhat higher temperatures. *S. aureus* is a gram-positive coccus occurring in irregular clumps, which can produce an intoxication caused by the ingestion of an enterotoxin secreted into the food during growth. The presence of the live organism in ingested food is irrelevant for the production of the disease (Garbutt 1997).

It is very important that hygiene problems are tackled systematically with the use of a hygiene evaluation study as a four-stage learning process (Almedom et al. 1997): (a) problem identification/defining the question(s); (b) gathering information systematically; (c) reviewing the information; and (d) reflecting on the results and/or taking remedial action. It is only with the use of this approach that effective interventions for hygiene improvements can be planned and designed.

The aims of the research were to (1) evaluate the total number of microorganisms on wood and plastic material used for pasta trays and (2) make a hygiene evaluation of analysed materials for application in the pasta industry. This research is aimed at answering the question, 'Does the tray material and/or location of the swab sample influence the colony forming unit (CFU)/20 cm^2?'

Materials and methods

The test plates RIDA®COUNT used in this study were as follows: RIDA®COUNT Total for total aerobic counts, RIDA®COUNT Yeast and MoldRapid for identification of yeast and mould, RIDA®COUNT *Staph.aureus* for identification of *Staphylococcus aureus* and RIDA®COUNT *E. coli*/Coliform for analysis of the presence of coliform bacteria and *Escherichia coli*. All test plates used were officially approved by AOAC-RI for all applications listed in the producer's specification.

Hygiene evaluation of wooden (*Abies* spp.) and plastic (PET) trays for pasta drying was analysed by swabbing and results compared in regard to total number of aerobic microorganisms, Enterobacteriaceae, *E. coli*, moulds, yeasts and *Staphylococcus aureus* in such materials. This study tested 105 plastic and 105 wooden

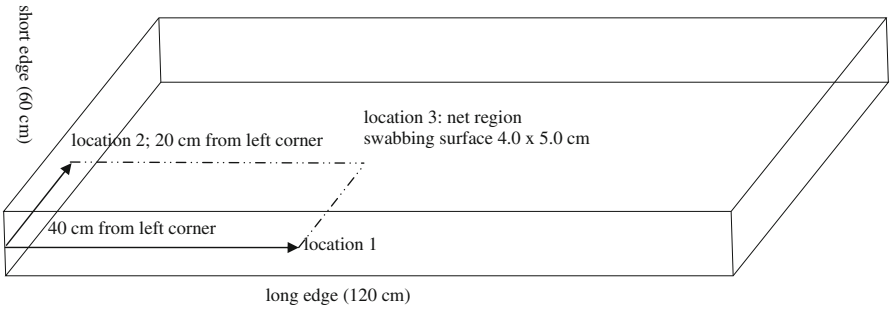

Fig. 1 Methodology of pasta tray swabbing

trays. Twenty-one trays were inserted in each trolley, which was made from stainless steel. The 1st, 11th and 21st trays were, therefore, swabbed in an area of 20 cm^2. Each tray was swabbed at three different locations: longest edge (1), shortest edge (2) and net region (3) (Fig. 1). Swabs from location 1 and 2 were taken on the inner side of the edge, 40 cm from the left corner for the long edge and 20 cm for the short edge using a surface area of 2.5 × 8.0 cm^2. Location 3 was determined as the cross-edged region of location 1 and 2. Sterile swabs on a plastic stick made of cotton were prepared with 5 ml of a sterile 0.9% NaCl solution. Plastic and wooden trays were washed in an industrial washing machine using a washing programme comprising 5 min of flushing with cold water, 5 min of washing with a hot (65°C) detergent solution, 3 min of flushing with hot water (85°C) and drying for 5 min with dry steam (105°C). Pasta was produced from durum wheat semolina, whole pasteurized egg and water on a continuous line using the premixing, kneading and pressing pasta dough trough brass model (die diameter: 1.0 mm). Fresh pasta was added onto trays and dried for 8 h according to the drying programme, and at the end of the process, prior to manual handling, the swab samples were taken.

After the swabbing, swabs were shaken for 2 min and 1 ml of solution was added onto each test plate. Plates for total aerobic count, Enterobacteriaceae, *E. coli* and *S. aureus* were incubated for 24 h at 30°C according to producers' instructions and then counted. The plates for moulds and yeasts were incubated for 72 h. The results of microbiological tests were processed by repeated measures analysis using the General Linear Model (GLM) procedure (De Temmerman et al. 2008). The statistical model included the main effects of the material, as well as the position of the sample swab. The least squares means of the experimental groups were obtained using the least square means (LSM) procedure, and results were compared at the 5% probability level (SAS 1999).

Results and discussion

Results concerning total aerobic counts (TAC), Enterobacteriaceae, *E. coli*, moulds, yeasts and *S. aureus* for swabs sampled from the two types of trays made from

Table 1 Results of swabbing on wooden and plastic pasta trays

Parameter (mean values of CFA)	Material		Statistical parameter
	Wood $n = 105$	Plastic $n = 105$	P value
TAC/20 cm^2			
Location 1, $n = 70$	14.6^{Aa}	865.9^{Bb}	<0.0001
Location 2, $n = 70$	14.3^{Aa}	53.6^{Ab}	0.011
Location 3, $n = 70$	11.3^{Aa}	90.1^{Ab}	<0.0001
P value	0.0655	<0.0001	
Enterobacteriaceae/20 cm^2			
Location 1, $n = 70$	19.4^{Aa}	46.9^{ABa}	0.065
Location 2, $n = 70$	10.4^{Aa}	8.0^{Aa}	0.614
Location 3, $n = 70$	23.0^{Aa}	68.6^{Bb}	0.014
P value	0.574	0.028	
E. coli/20 cm^2			
Location 1, $n = 70$	0.0^{A}	0.0^{A}	–
Location 2, $n = 70$	0.0^{A}	0.0^{A}	–
Location 3, $n = 70$	0.0^{A}	0.0^{A}	–
P value	–	–	
S. aureus/20 cm^2			
Location 1, $n = 70$	0.1^{Aa}	125.6^{Bb}	<0.0001
Location 2, $n = 70$	0.1^{Aa}	13.9^{Ab}	0.008
Location 3, $n = 70$	0.6^{Aa}	21.3^{Ab}	0.001
P value	1.000	<0.0001	
Moulds/20 cm^2			
Location 1, $n = 70$	0.3^{Aa}	3.0^{Bb}	0.013
Location 2, $n = 70$	0.0^{Aa}	2.0^{ABb}	0.025
Location 3, $n = 70$	0.1^{Aa}	0.1^{Ab}	0.001
P value	0.361	0.024	
Yeasts/20 cm2			
Location 1, $n = 70$	0.1^{Aa}	59.1^{Bb}	< 0.0001
Location 2, $n = 70$	0.0^{Aa}	2.9^{Ab}	0.002
Location 3, $n = 70$	0.1^{Aa}	15.4^{Ab}	0.052
P value	0.604	0.019	

n: number of observations; highly significant, $P \leq 0.001$; very significant, $P \leq 0.01$; significant, $P \leq 0.05$; not significant, $P > 0.05$; Values followed by a different *capital letter* are significantly different down the same column for the Duncan (0.05) test; Values followed by a different *small letter* are significantly different along the row for the Duncan (0.05) test. *TAC,* total aerobic count; *CFU,* colony forming unit

different materials are given in Table 1. Comparisons along a row within Table 1 show a difference in CFU for each investigated material according to the location of the swab sample. Data within columns show CFU differences with respect to location on a certain material. Values of TAC/20 cm^2 for wooden trays were significantly lower ($P \leq 0.001$) for location 1 and 3 when compared to plastic trays.

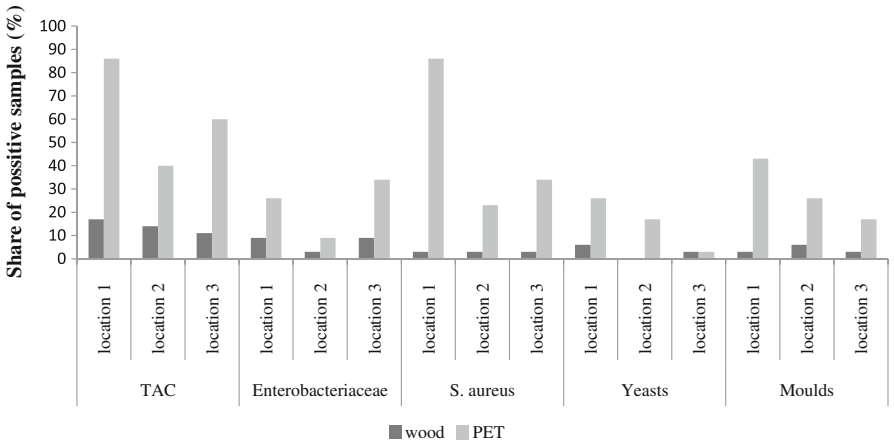

Fig. 2 Percentage of positive swabs taken from wooden and plastic (PET) materials ($N = 210$)

Results also show that values for other investigated microorganisms on wood were significantly lower ($P \leq 0.05$) when compared to plastic. Similar results are shown in Fig. 2 for the percentage of positive swabs. Much higher percentages of positive results were obtained in all samples from PET trays compared to wooden trays. Schönwälder et al. (2000) indicated that there seems to be evidence that pine, especially the heartwood of pine, is superior to other frequently used species. In addition to the hygroscopic properties of wood, the high content of extractives in certain species such as pine proved to have a good antibacterial effect. Beyer and Guðbjörnsdóttir (2002) showed that not only the species of woods but the moisture of wood is also important for the level of hygiene in connection with food. Increasing wood moisture implies better conditions of life and proliferation for bacteria, and dry conditions are, therefore, the way to prevent bacterial growth. In contrast, Gough and Dodd (1998) studied survival and disinfection of *Salmonella typhimurium* on chopping board surfaces made from wood and plastic and found that there was no significant difference between wood and similarly treated plastic surfaces. Milling et al. (2005) studied microbial survival on pine (*Pinus silvestris*), larch (*Larix decidua*) and maple (*Acer pseudoplatanus*) wood, which are commonly used in Europe, and found that the total number of bacteria on wood was smaller when compared to plastic. Different bacterial species showed a completely different level of survival on wooden samples, followed by enterococci and streptococci (Milling et al. 2005).

Since extreme conditions are present in the drying room, a material used in such processes must be durable. From a technological point of view, plastic is unsuitable since it undergoes twisting, expansion and shrinkage under drying-room conditions. During the heating stage of the drying process, plastic trays can expand so intensively that they cannot be moved in the transporting trolley. Furthermore, during the cooling stage, the trays may undergo such shrinkage that they fall out of the trolley. Moreover, plastic trays are also heavier than wooden trays and represent an unnecessary burden for workers. The market also makes available trays made of

aluminium, which are lighter than other trays but the costs are extremely high. Wooden trays are more rigid, lighter and more resistant to changes in conditions. The average air temperature in the drying chamber is 65°C, the time of drying varies due to pasta type and is between 6 and 14 h, the relative humidity decreases from 28 to 34% to below 12%, and the water activity in the final product is lower than 0.6 (Mondelli 2005). Nevertheless, if wood is used in the food industry, it has to be cleaned and maintained properly to minimize not only microbiological growth but also chemical and physical hazards in the process of food making.

The results show that the total number of microorganisms (CFU/20 cm^2) is significantly lower on wooden frames compared to plastic frames irrespective of location and that 30% of swabs sampled from plastic frames exceeded 200 CFU/20 cm^2, whereas the value for wooden frames was only 3%. In the case of Enterobacteriaceae, there was no statistically significant difference (CFU/20 cm^2) between wooden and plastic frames for any location. Nevertheless, 9% of swabs sampled from plastic frames and 6% of those sampled from wooden frames exceeded a level of 200 CFU/20 cm^2. *Escherichia coli* colonies (in CFU/20 cm^2) were not present in any of the samples. The number of colonies of *Staphylococcus aureus* was significantly lower on wooden than plastic frames, irrespective of the location on the frame: 54% of swabs on plastic frames were positive, while 3% of those on wooden frames were positive. The levels of moulds and yeasts were significantly lower on wooden frames compared to plastic regardless of location. In the case of moulds, 21% of swabs on plastic frames and 3% of swabs on wooden frames were positive. In the case of yeasts, 34% of swabs on plastic frames were positive, whereas only 1% of swabs were positive on wooden frames.

Conclusion

Food safety involves additional aspects such as nutritional value and sensory qualities, which contribute to the determination of food quality parameters. In the production process, food can come in contact with various materials, and it is, therefore, vital that these different kinds of materials do not have a negative impact on the food product. In the last few decades, the use of wood in food production processes has decreased and other materials such as plastic, 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 (Lauzon 1998). The results of this research show that the number and species of microorganisms are statistically different on plastic (PET) and wooden frames ($P \leq 0.05$). The results confirm that the material has a significant impact on the presence of colonies in CFU/20 cm^2, except in the case of Enterobacteriaceae, where there was no significant difference. It is evident from the results of this study that the materials used for the pasta tray influence the colony forming unit (CFU)/20 cm^2, and it can be concluded that wood is a hygienic material than plastic (PET). There are also several other studies which show that wood can be as hygienic as other materials, and some species of wood even have antimicrobial properties

(Schönwälder et al. 2000; Worfel et al. 1995; Beyer and Guðbjörnsdóttir 2002; Milling et al. 2005).

This study of hygiene evaluation supports the conclusion that wood is appropriate in the food industry from a hygienic and technological point of view.

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