Rocz Panstw Zakl Hig 2018;69(1):63-70

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ORIGINAL ARTICLE

EVALUATION OF FOOD STORAGE RACKS AVAILABLE ON THE POLISH MARKET IN THE HYGIENIC CONTEXT

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ABSTRACT

Background. Providing safe food products to the consumer depends on the material and technology used and adherence to hygienic practices, throughout the production process. The degree of microbial contamination of a surface is an important indicator of equipment cleanliness and effectiveness of cleaning and disinfection. Used material, construction solutions and quality of the applied devices also have an effect on hygienic status.

Objective. The objective of the present study was to evaluate the influence of the design and construction material of selected food storage racks, available on the Polish market, on their hygienic status.

Material and methods. The study was based on determination of the capability of microbial growth on the surface of the racks and the effectiveness of their cleaning. Microbiological cleanliness on the surface of the racks was monitored by the contact plates which are able to estimate the total number of microorganisms. Examination of effectiveness of cleaning was conducted by the use of ATP bioluminescence method.

Results. This experiment has proven a significant influence of adopted construction solutions on the hygienic status of the examined racks. Presence of antibacterial layer and a choice of the appropriate construction material characterized by a low surface roughness impedes the microbial growth and increases the effectiveness of cleaning.

Conclusions. Design solutions have significant impact on the hygienic status of shelves. Selection of a suitable material for the construction of racks can greatly reduce the possibility of the development of microorganism, despite the low efficiency of the cleaning. The application of antimicrobial coatings inhibits microbial growth.

Key words: *storage racks, microbiological cleanliness of surfaces, effectiveness of cleaning processes, ATP bioluminescence, hygiene of racks*

STRESZCZENIE

Wprowadzenie. Dostarczanie konsumentowi produktów spożywczych o jak najwyższej jakości, w tym bezpiecznych, uzależnione jest od wykorzystanych surowców, zastosowanej technologii oraz zachowania warunków higienicznych w całym procesie wytwórczym. Stopień zanieczyszczenia mikrobiologicznego powierzchni jest ważnym wskaźnikiem czystości urządzeń oraz prawidłowości procesów mycia i dezynfekcji. Wpływ na higienę urządzeń mają takie czynniki jak zastosowany materiał oraz rozwiązania konstrukcyjne, a także jakość wykonania urządzenia.

Cel. Celem pracy była ocena wpływu konstrukcji i użytego materiału na jakość higieniczną wybranych regałów magazynowych, dostępnych na polskim rynku.

Materiał i metody. W badaniu sprawdzono zdolność wzrostu drobnoustrojów (ogólna liczba drobnoustrojów) na powierzchniach wybranych regałów. Czystość mikrobiologiczną na powierzchni regałów monitorowano za pomocą płytek kontaktowych do oznaczania ogólnej liczby drobnoustrojów. Oznaczenia wykonano zgodnie z normą PN-ISO 18593 Badanie skuteczności procesu mycia przeprowadzono z wykorzystaniem metody bioluminescencyjnego pomiaru ATP.

Wyniki. Doświadczenie wykazało znaczący wpływ zastosowanych rozwiązań konstrukcyjnych na higienę ocenianych regałów. Badania wykazały istotny wpływ rodzaju regału na poziom zanieczyszczenia mikrobiologicznego odnotowanego na powierzchni roboczej regałów oraz na powierzchni połączeń półek ze słupkami nośnymi. Analiza statystyczna wykazała, że w przypadku każdej z prób rodzaj regału miał wpływ na osiągnięte wyniki.

Wnioski. Rozwiązania projektowe mają istotny wpływ na higieniczną jakość półek. Dobór odpowiedniego materiału do budowy regałów może znacznie ograniczyć możliwość rozwoju mikroorganizmów, pomimo niskiej efektywności czyszczenia. Zastosowanie powłok antybakteryjnych hamuje wzrost drobnoustrojów.

Słowa kluczowe: *regały magazynowe, mikrobiologiczna czystość powierzchni, efektywność procesu mycia, bioluminescencyjny pomiar ATP, higiena regałów*

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INTRODUCTION

Meals consumed at catering establishments are a common cause of food poisoning [4, 16]. The data published by the European Food Safety Authority (EFSA) [10] show that in 2015 there were 36,4% of verified sources of food poisoning associated with the services provided by the catering establishments, such as restaurants, cafés, pubs, bars, and by the hotel gastronomy. Less frequently, food poisoning was caused by meals served in canteens.

Responsibility for food safety rests with the food producers [22, 26]. Obtaining safe products of the highest quality depends not only on the material and technology used, but also on the adherence to hygienic practices, throughout the production process [7, 20, 27). According to *Scott* [24], nearly 39% of recorded food poisonings was the result of cross-contaminations. The source of the contaminations can be, among others: employees at food establishments [27, 28] construction of technological internal and external surfaces [19, 23], inadequate planning of a production line and the functional layout of a building, as well as carelessly conducted cleaning and disinfection [12, 15].

The degree of microbial contamination of a surface is an important indicator of equipment cleanliness and effectiveness of cleaning and disinfection [18]. Used material, construction solutions and quality of the applied devices also have an effect on its hygienic status [1, 8, 9, 11].

The objective of the present study was to evaluate the influence of the design and construction material of selected food storage racks available on the market on their hygienic status. The study was based on determination of the capability of microbial growth on the surface of food storage racks and the effectiveness of their cleaning.

MATERIALS AND METHODS

For the purposes of the study, an evaluation of three types of food storage racks, available on the Polish market, was made. Detailed characteristics of the these racks are presented in Table 1. These characteristics include elements such as: construction materials, way of installation shelves on support and shelves construction. The racks were set in a separate room, in which the following conditions were ensured: humidity 80-85%, room temperature (20-22^{o}C).

Table 1. Characteristics of the evaluated racks

	Rack 1	*Rack 2*	*Rack 3*
Construction materials	support and shelves: carbon steel coated with epoxy resin and antibacterial coating*	support and shelves: steel coated with a layer of chrome-nickel, secured an additional protective lacquer	support: anodized aluminum, shelves: rack made of anodized aluminum, modular inserts made of polyethylene
Way of installation shelves on support	clamping system, the possibility of adjusting the height as 2.5 cm	clamping system, the possibility of adjusting the height as 2.5 cm	rack twisted with support behind assistance of screw, support have holes for assembling shelves at 15 cm
Shelves construction	wire shelves	wire shelves	inserts with ventilation holes, surface of rough to prevent slippage of stored materials

Own study based on [11]

* Composition of the antibacterial coating is reserved by the producer; it is built into the molecular structure of the shelf what provides even distribution in the cross-section and on the surface

Material preparation for testing and sampling

In order to simulate conditions characteristic for catering industry, the racks soiled with a mixture containing organic compounds. The mixture was prepared from the following ingredients: stock prepared from bouillon cubes (the number of cubes in 1000 cm^3 of water according to manufacturer's recipe), butter (115 g), cream with 18% of fat content (115 g), flour (400 g) and egg yolk (190 g) [13]. The ingredients were mixed until homogenous. The mixture was prepared directly before its use.

Racks 1, 2 and 3 soiled with the sponge and with the prepared mixture (temperature of emulsion about 20 ^{o}C) in an amount of 0.02 g/cm^2 and left for 2 hours at room temperature. After this time, the racks were dismantled, washed by the use of professional cleaner kitchen surfaces (concentration 2,5%) having the following composition: secondary alkylosufonians, glycols - glycol ethers, and then rinsed under running water (10 min). Cleaner was apply onto clean surface and let it work for 15 min. Application of the mixture and the cleaning were each time performed by the same person in order to make sure that all activities were carried out under comparable conditions. After cleaning the racks were visually clean.

The samples for examination cleanliness and adenosine triphosphate (ATP) measurement were collected on "day 0" from clean racks (test 0), and from the washed areas which had been earlier dirtied with the mixture (test 1), (Figure 1). Measurements were performed on the operational (A1, A2, A3) and on the one connecting shelves and their support (B1, B2, B3), (Figure 2). In each shelf, two samples were collected according to the scheme shown in Figure 3. Field markings were determined using disinfected with alcohol line. Sampling of area B were taken alternately: in one day of testing - right side of rack (front, rear connection), the second day of testing - left side (front, rear connection).

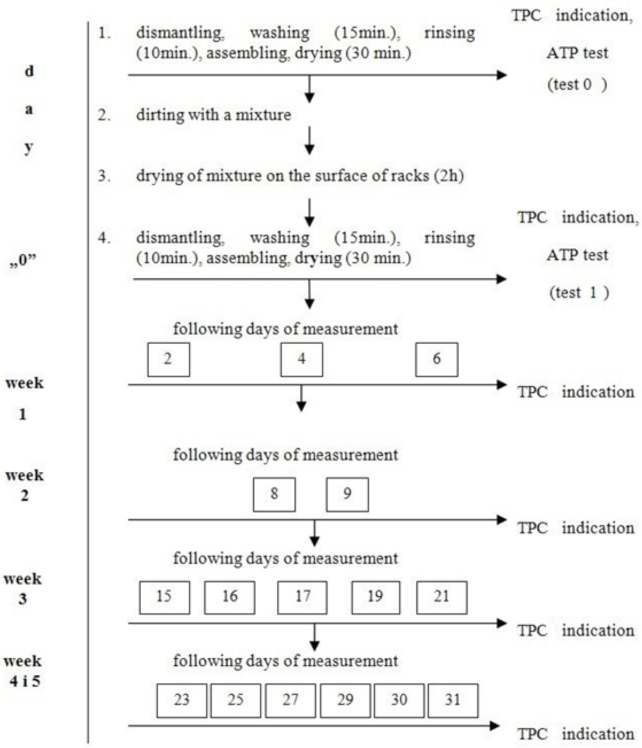


Figure 1. Scheme of experience. TPC (Total Plate Count)

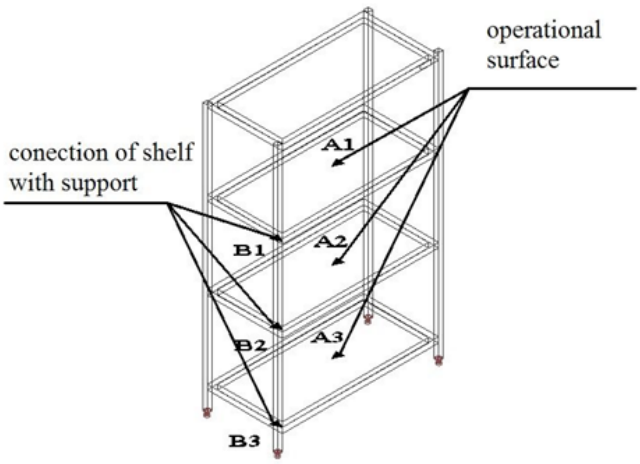


Figure 2. Areas of measurement of the total count of microorganisms (total plate count – TPC) and the ATP (adenosine triphosphate). Source: Own study based on [17]

	15	23	31		15'	23'	31'	
2	9	21	30		9'	21'	30'	2'
1	8	19	29		8'	19'	29'	1'
0	6	17	27		6'	17'	27'	0'
	4	16	25		4'	16'	25'	

Explanatory note: The numbers are in accordance with successive days markings shown in Figure 1

Figure 3. Scheme of sampling on operational surface

The choice of area A was dictated by the fact that it directly contacts the master packages or surfaces of products themselves, which can cause cross-contamination of raw materials and food products. Whereas, the surface connecting shelves and their support (area B) is difficult to reach during cleaning. Thus, they are potentially dangerous areas in terms of growth of microorganisms.

The cleaning of food equipment in catering establishments depends on the protocols of that facilities. Factors influencing the choice the choice of hygiene practice methods include cost, time, staff, ease of use, management needs, and nature of the food contact surfaces [5].

Duration of the experiment and the sampling frequency were determined on the basis of long experience of the research team (frequent visits to the backrooms of catering establishments caused by various renovations and modernizations as well as implementation and auditing of food safety management systems). Interviews conducted among employees of catering establishments and people engaged in HACCP audits show that in most cases, during preparation of GMP / GHP procedures, cleaning and disinfection of racks is planned 2 - 4 times a month. For this reason, due to generally accepted GMP/GHP procedures, frequency of cleaning and disinfection, which is up to every 14 days, the experiment samples in week 1 and 2 were performed with less frequency. Analysis performed in weeks 3, 4 and 5 were intensified to check the hygienic status of the racks in whose cases the proper cleaning and disinfection procedures were not obeyed.

Methods of microbiological determinations

Determination of the total count of microorganisms (Total Plate Count – TPC) was performed by the contact method in accordance with ISO 18593 [14], by the use of contact plates Rodac ConTact Test with neutralizers. The area of a plate equaled 25 cm^2. The plates were incubated for 24 hours at the temperature of 37 °C. Subsequently counting of the number of grown colonies was performed. The result was reported as the count of CFU per 25 cm^2.

TPC obtained in the experiment was compared with the indicators in Polish Standard PN-A-82055-19 [21], (Table 2). This document corresponds to determination of microbial contamination of surfaces as well as evaluation of the effectiveness of disinfectants and detergents in case of meat processing plants. However, due to the fact that the investigated storage racks are designed to store all food products, including meat, it was assumed that they should comply with the requirements of the norm.

Table 2. The indicators and evaluation of microbiological contamination of surface depending on the total count of oxygen microorganisms on 25 cm^2

Number of microorganisms CFU/25cm^2	Indicator	Evaluation
0 ÷ 2,0 x 10^0	0	Excellent
3,0 x 10^0 ÷ 9,0 x 10^0	1	Very good
1,0 x 10^1 ÷ 2,9 x 10^1	2	Good
3,0 x 10^1 ÷ 9,9 x 10^1	3	Sufficient
1,0 x 10^2 and above	4	Insufficient

Source: PN-A-82055-19 [21]

Methods of bioluminescent ATP measurement

ATP measurement was performed by the use of Uni-Lite Xcel apparatus by Biotrace and the swabs in the form of pens in test tubes which are compatible with the device. After the swabbing, each pen was placed in a test tube for the reaction to be performed. Subsequently, the tube was placed in the apparatus and after 15 - 20 s, the results could be read as relative light units (RLU).

Statistical analysis

Statistical analysis was done by the use of STATGRAPHICS 5.1. Data analysis was performed by the use of one-way analysis of variance (one-way ANOVA). Testing was performed at a significance level of $P <0,05$.

RESULTS AND DISCUSSION

Conducted assay showed that on the day of cleaning ("day 0"), the lowest values of RLU/25 cm^2 (Figure 4) and cfu/25 cm^2, both on the surface of the shelves and on the surface connecting shelves and their support (Tables 3 and 4), were found in case of the rack 1. Whereas, the highest values were characteristic for the rack 3.

Table 3. Average value of TPC [cfu/25cm^2] noted on the operational surfaces of evaluated racks

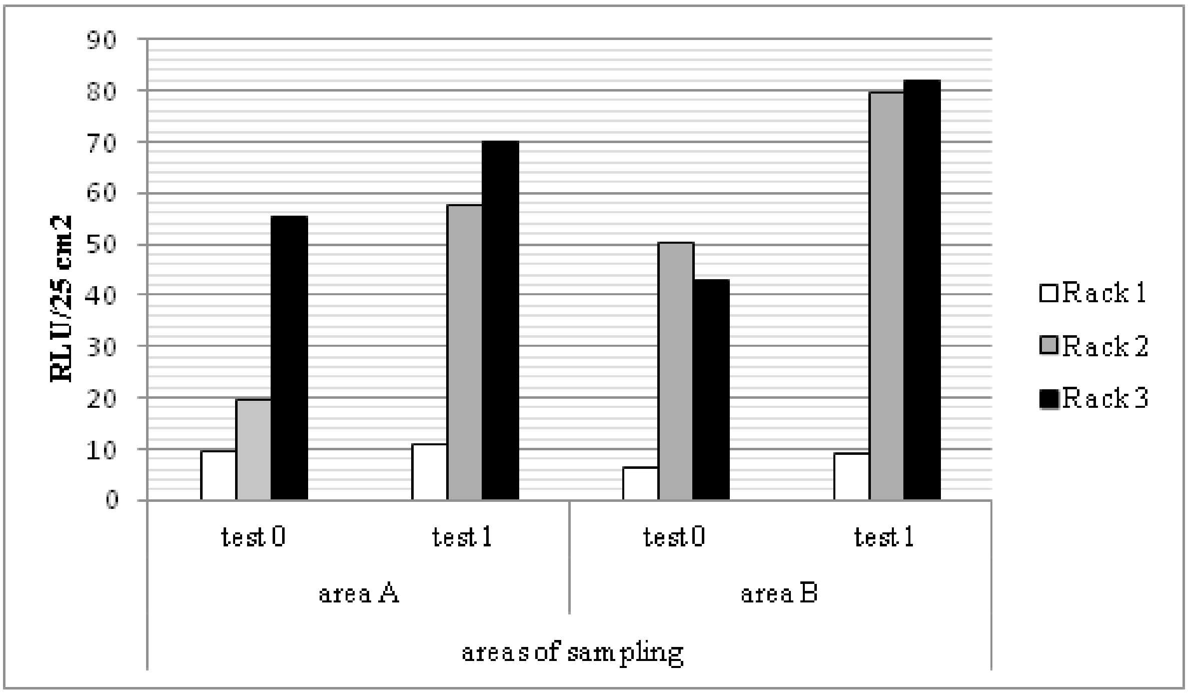
Sample number	Kind of racks		
	Rack 1	*Rack 2*	*Rack 3*
0	2.33 ± 1.21	7.50 ± 2.43	23.50 ± 5.50
1	4.83 ± 2.48	8.50 ± 3.619	12.83 ± 0.98
2	3.00 ± 0.63	6.50 ± 3.56	9.50 ± 1.05
4	3.50 ± 1.05	8.67 ± 1.75	11.50 ± 2.43
6	7.67 ± 1.21	19.67 ± 4.03	35.17 ± 7.39
8	8.83 ± 1.47	23.83 ± 5.60	51.17 ± 8.03
9	7.50 ± 1.38	23.33 ± 3.33	51.50 ± 6.22
15	8.33 ± 1.51	35.00 ± 7.07	91.00 ± 15.26
16	8.17 ± 2.79	42.50 ± 5.79	115.33 ± 16.03
17	13.67 ± 1.21	59.67 ± 6.53	137.00 ± 14.67
19	9.00 ± 2.61	59.83 ± 6.11	154.67 ± 17.91
21	9.00 ± 2.37	60.83 ± 7.28	166.67 ± 20.41
23	9.50 ± 2.81	82.33 ± 11.15	270.83 ± 43.06
25	10.67 ± 1.21	87.67 ± 6.89	354.17 ± 29.23
27	8.33 ± 1.03	87.67 ± 13.31	337.50 ± 37.91
29	12.17 ± 1.47	91.00 ± 6.23	345.83 ± 45.87
30	14.17 ± 1.60	101.00 ± 17.32	391.67 ± 14.43
31	14.00 ± 2.28	103.50 ± 17.33	TN

Explanatory note: TN – too numerous to count;

Table 4. Average value of TPC [cfu/25cm^2] noted on the surfaces connecting shelves and supports

Sample number	Kind of racks		
	Rack 1	*Rack 2*	*Rack 3*
0	13.17 ± 3.37	22.50 ± 5.24	20.17 ± 5.60
1	9.00 ± 2.53	12.00 ± 3.63	10.00 ± 4.19
2	4.00 ± 1.09	7.00 ± 1.79	4.83 ± 2.04
4	3.50 ± 1.38	6.17 ± 1.33	5.00 ± 1.26
6	3.50 ± 1.05	8.50 ± 2.81	8.17 ± 2.99
8	2.83 ± 1.72	7.17 ± 2.64	8.33 ± 2.58
9	3.33 ± 1.37	6.33 ± 2.42	8.67 ± 2.25
15	2.50 ± 1.52	8.33 ± 2.87	8.83 ± 5.74
16	2.83 ± 1.47	8.67 ± 3.01	8.00 ± 3.29
17	3.00 ± 1.09	9.83 ± 2.48	9.33 ± 3.88
19	1.33 ± 1.21	7.50 ± 2.07	8.00 ± 3.35
21.	1.83 ± 1.47	7.83 ± 2.40	8.33 ± 2.58
23	1.83 ±0.75	8.50 ± 3.94	9.17 ± 1.94
25	2.00 ± 0.89	8.00 ± 4.73	13.67 ± 4.46
27	2.83 ± 1.17	7.33 ± 3.08	12.83 ± 3.43
29	2.50 ± 1.87	7.50 ± 2.59	13.50 ± 2.74
30	2.33 ± 1.51	7.83 ± 3.06	18.83 ± 4.96
31	2.33 ± 1.63	8.33 ± 3.93	18.00 ± 4.77

The analysis of the ATP measurements on the surfaces of racks 2 and 3 present after cleaning (test 0), and after cleaning the surfaces dirtied with the mixture (test 1) proves the low effectiveness of the cleaning of the operational surfaces (areas A) and of the surfaces connecting shelves and their support (areas B). In case of the rack 2, the value of RLU/25 cm^2 found on the operational surface of the shelves after the second cleaning (test 1) was on average about 38 units higher than in the survey carried out after the first cleaning (test 0), while in case of the surfaces connecting shelves and their support the value was 29 units higher. In case of the rack 3, differences between the second and the first cleaning of areas A and B were respectively 14,5 and 39 RLU/25 cm^2. The same assay performed in case of the rack A showed high effectiveness of cleaning of areas A as well as B (Figure 4).



Explanatory notes: area A – operational surfaces; area B – surfaces connecting shelves and their support; test 0 – measurement after first cleaning (day "0"); test 1 – measurement after cleaning the surfaces dirtied with the mixture (day "0")

Figure 4. Results of the bioluminescent ATP measurement on the surfaces of racks

The microbiological assay taken on "day 0", on the surfaces connecting shelves and their support, in case of every rack surveyed, prove that the cleaning caused reduction of TPC (Table 4). Whereas, the ATP measurement performed in areas B shows an increase of value of RLU/25cm^2 after cleaning of the surfaces previously dirtied with the special mixture. The results show that the materials used for construction of racks as well as their design itself, particularly in case of racks 2 and 3, hinder complete removal of the organic contamination deriving from raw materials or food of plant and animal origins under the cleaning.

It should be emphasized that, under the conditions of the present experiment, the rack 1 complied with the requirements imposed on equipment used in hospitals, which were defined by *Anderson* et al. [2] at the level not higher than 100 RLU/100 cm^2.

On the basis of TPC assay, it was concluded that the differences between the examined racks, due to the level of microbial contamination, were statistically significant ($P < 0.05$). This relation was observed in case of the TPC determined on the operational surfaces, as well as the areas connecting shelves and their support (Table 4).

The lowest number of microorganisms during the whole experiment, was determined on the shelves of the rack 1, whose characteristic is the presence of anti-bacterial coating.

Performed assay (Table 3) show that during the study period, on the operating surface of the rack 1 there was a 4 - fold increase in the number of microorganisms (from 3.5 to 14 cfu/25cm^2), more than a 10 - fold one in case of the rack 2 (from 8, 5 to 104 cfu/25cm^2) and an over 40 - fold one in case of the rack 3 (from 12 to more than 400 cfu/25cm^2). On the last day of the experiment (day 31), on the operational surface of the rack 3, the number of microorganisms was reported to as too numerous to count (TN), and therefore the value is not included in the Table 3.

The design solution of the shelves applied in case of racks 1 and 2 (wire shelves) resulted in the fact that the contact surface of raw material with shelves is much weaker compared to the solution proposed in case of the rack 3 (polyethylene plate with ventilation holes), which was the cause of finding the lower total number of microorganisms (Table 3). In addition, the shelves of the rack 3 are characterized by a rough surface intended to prevent slipping of stored materials. According to *Donlan* [8] the adhesion to the surface is dependent upon among others the physicochemical properties of the surface such as texture (rough or smooth) or their hydrophobicity.

In favorable circumstances, bacteria are capable of forming a biofilm which is defined as an aggregation of microorganism attached to and growing on a surface [6]. Biofilms form a reservoir of contamination that persist where cleaning of the manufacturing plant is ineffective [25].

Assay of the TPC performed in case of areas B (Figure 2) indicate a significantly lower level of microbial contamination (maximum value: 22.5 cfu/25 cm^2) in comparison to the operational surface of shelves (maximum value: 392 cfu/25 cm^2). When it comes to the surfaces connecting shelves and their support the lowest value of TPC was stated in case of the rack 1, whereas the highest one was found in case of the rack 3 (Table 4).

In case of the surfaces connecting shelves and the support of the racks 1, 2 and 3, on "day 0", a reduction of TPC after the second cleaning process was noted. The assay of microorganisms show the effectiveness of the process. In every three of the analyzed variants, after 48 hours subsequent to the cleaning the decrease of TPC was noticed. This may indicate that microbial cells that remained on the examined surfaces after performance of a double washing on the "day 0", began to die out due to environmental shortages of nutrients necessary for the their development . In the following days of the experiment, it was found that in case of the rack 1 as well as 2, the changes of TPC were not statistically significant (p >0.05). Whereas, in case of the rack 3, an increase in the population of microorganisms was observed in the last week of the experiment (from day 23). The TPC found on the surfaces connecting the examined shelves and their support show that the use of antimicrobial coating, as part of the structural material, effectively hinders the growth of micro flora, which allows cleaning to be performed less frequently. The least desirable solution, due to the greatest increase of TPC (Table 4), was proposed in case of the rack 3, whose aluminum frame with polyethylene cartridges was attached to the supports with bolts. This design solution impedes performance of effective cleaning, due to the hindered access to fissures, which in turn might have accelerated the formation of biofilm on the surface.

After comparing the assay of TPC with the indicators and evaluation of the microbiological contamination of surfaces mentioned in the Polish Standard PN-A-82055-19 (Table 2), it was stated that during the first three weeks of the experiment, shelves of the rack 1 were characterized by very high microbiological cleanliness, i.e. ≤9 cfu /25 cm^2 (Figure 5). Whereas, the lowest rating was obtained by the shelf 3.

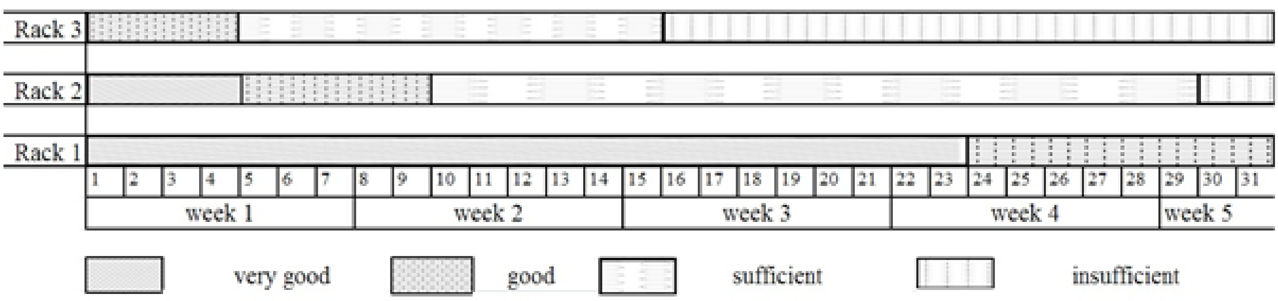


Figure 5. Evaluation of operational surfaces of evaluated racks according to the Polish Standard PN-A- 82055-19 [21]

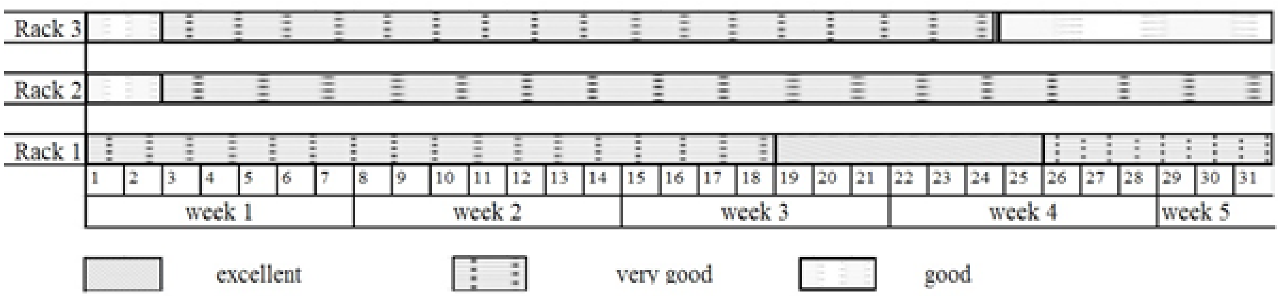


Figure 6. Evaluation of the surfaces connecting shelves and their support of evaluated racks according to the Polish Standard PN-A- 82055-19 [21]

Also in case of the surfaces connecting shelves and their support, the highest rating, in accordance with the PN-A-82055-19 was obtained by the rack 1 (Figure 6).

According to the decision No. 2001/471/EC of the European Commission on the cleaned and disinfected surfaces in meat processing plants, TPC should be in the range of 0 - 10 cfu/10 cm^2 [3]. The required number of cfu, during the entire experiment, was found only in case of assay performed for the rack 1.

CONCLUSIONS

1. Design solutions have significant impact on the hygienic status of shelves. Rounded and smooth edges greatly enhance cleaning and reduce the possibility of microbial growth. Sharp edges, complicated design of jointing and increased roughness facilitate development of microorganisms and reduce the effectiveness of cleaning.
2. Selection of a suitable material for the construction of food storage racks can greatly reduce the possibility of the development of microorganism, despite the low efficiency of the cleaning. Rack 2 with the lowest performance indicators of wash, thanks to the chrome-nickel steel, had a satisfying values of the total number of microorganisms. The rough surface of the material of rack 3 had the greatest extent conducive to microbial growth, despite the fact that the washing process proved to be effective against it.
3. Area of rack 1 with the antibacterial coating, was characterized by the lowest microbial contamination and the ATP measurement showed the highest cleaning efficiency among the examined racks.

Conflict of interest

The authors declare no conflict of interest.

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Received: 21.08.2017
Accepted: 17.11.2017