

The methods analysis of hazards and product defects in food processing

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Citation: Przystupa K. (2018): The methods analysis of hazards and product defects in food processing. Czech J. Food Sci., 37: 44–50.

Abstract: The paper pertains to the issue of quality assurance methods. Particular emphasis is placed upon the examination of hazards and possible product defects in food processing. At present, Polish regulations oblige any food processing entity to implement HACCP system. The system is perceived as a universal vaccine preventing the emergence of possible hazards or reducing the risk to an acceptable level. As far as defects are concerned, these are either disregarded altogether or do not occur at all. Meanwhile, the practice proves the case is not so. The research aspect of the paper revolves around an attempt to transplant solutions primarily applied in the automotive sector onto food processing industry. The practical aspect of the paper is manifested in the analysis of causes behind defects and hazards conducted on the basis of bakery industry. Potential hazards and product defects emerging from the process were identified in the course of the study. In addition, in order to eliminate these, their level was established with the application of various methods.

Keywords: food processing; HACCP; statistical control; product defects

In light of HACCP system (Hazard Analysis and Critical Control Points), in food processing industry, the emergence of product defects is motivated by the presence of hazards which were not eliminated at a specific level of the technological process, or whose level was not reduced to an acceptable level, i.e. one safe for consumers' health (MORTIMORE 2013). Three main categories of hazards can be enumerated in such a context:

- (1) physical hazards (Z1);
- (2) chemical hazards (Z2);
- (3) biological hazards (Z3).

Such an interpretation of quality does not automatically ensure defect-free products. Any negative characteristic of a product which reduces its consumer value or even disqualifies it and makes it unsuitable for consumption constitutes a product defect. With regard to baked goods, defects may be classified into

the following groups: external appearance defects, crumb's defects, taste and aroma defects, staling.

As far as baked goods are concerned, e.g. rye or mixed bread, the most frequent defects include the following:

- (1) External appearance defects:
 - (a) shape defects (W1);
 - (b) low volume of the loaf (W2);
 - (c) crust defects (W3).
- (2) Internal defects:
 - (a) taste and aroma defects (W4);
 - (b) crumb's defects (W5).

Both hazards and defects can be prevented. Two types of measures – preventive and corrective – are taken to this effect. The type of the measure undertaken depends upon the cause and stage in the technological process the problem was identified in. Some hazards are limited in the framework of Good

Manufacturing Practice (PRZYSTUPA 2007; KOKKINAKIS *et al.* 2008).

By definition, HACCP determines which threats ought to be considered as critical and which stage they ought to be focused upon (Critical Control Points). The decision tree approach constitutes a popular tool applied in the process Figure 1.

In food processing practice, no other methods aiming to identify hazards have emerged.

On the other hand, the literature associated with product quality management offers a considerable number of practical methods and tools facilitating product quality control (TURLEJSKA 2003; BAKRI 2017).

The practical goal of the article is to show the evaluation of quality assurance methods in the production of foodstuffs on the example of bread production. The article presents alternative methods of food safety analysis, including those that take into account product defects, not only the hazards.

The scientific objective of the article is to show how to transfer methods commonly used in the automotive industry to the food sector, in which the HACCP system is obligatory. It should be noted that the presented considerations are not aimed at eliminating the HACCP system, but rather to support it.

MATERIAL AND METHODS

Popular classifications encompass (ADAM 1994; PŁASKA 2000) the following: traditional magnificent seven tools, new magnificent seven tools, and a group of other tools. The traditional tools include: check sheet, histogram, control chart, Ishikawa diagram, Pareto chart, Scatter diagram and Flow chart.

The new magnificent seven tools encompass: affinity diagram, interrelationship diagram, tree diagram, matrix diagram, matrix data analysis chart, process decision program chart, activity network diagram. The remaining tools, which have not been outlined in the above groups, but are universally applied in quality management, especially in automotive sector, include: FMEA analysis, brainstorming, 5S method, SMED method, six sigma method, 8D method (DAHLGAARD 2006; ERICSON 2015).

Rye bread production process constitutes the object of the study (Figure 2). The process is semi-automatic and universally implemented in small and medium facilities. The bakery the data was extracted from

operates on the basis of an implemented and documented product quality system. The owner's representative for quality and product health and safety is employed in the bakery.

RESULTS AND DISCUSSION

Decision tree method. The analysis revolves around following the algorithm outlined in Figure 1. The analysis is conducted for each stage of the technological process (Figure 2) (GERDES 2017).

The analysis provides information regarding which stage, i.e. critical control point (CCP), the hazard is the most likely to escape control in and become impossible to be eliminated in subsequent stages. However, the analysis does not offer the assessment of the significance regarding the identified CCPs. In addition, it does not grade and rank the identified critical control points. It does not encompass product defects either. It strictly pertains to hazards emerging at individual stages of the technological process. The analysis conducted in the bakery revealed that the following constitute critical points in the facility: receipt of raw materials (CCP1) and baking (CCP2).

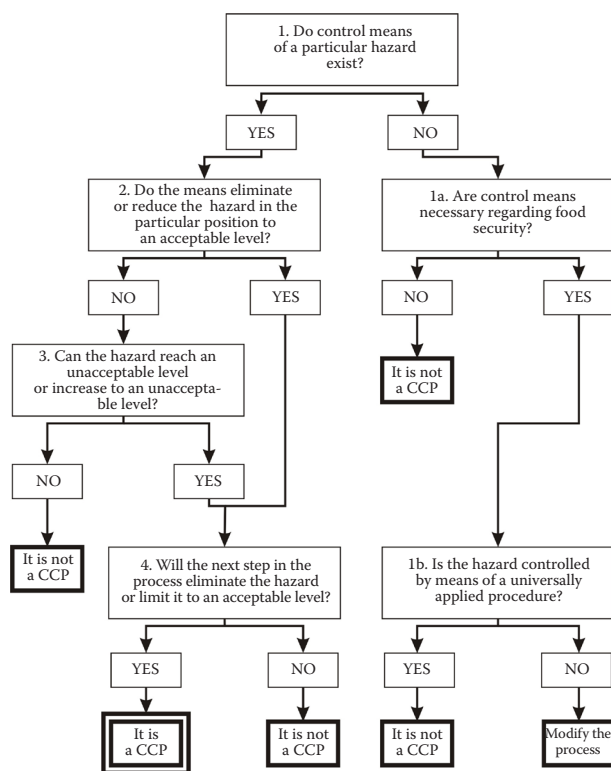


Figure 1. Decision tree

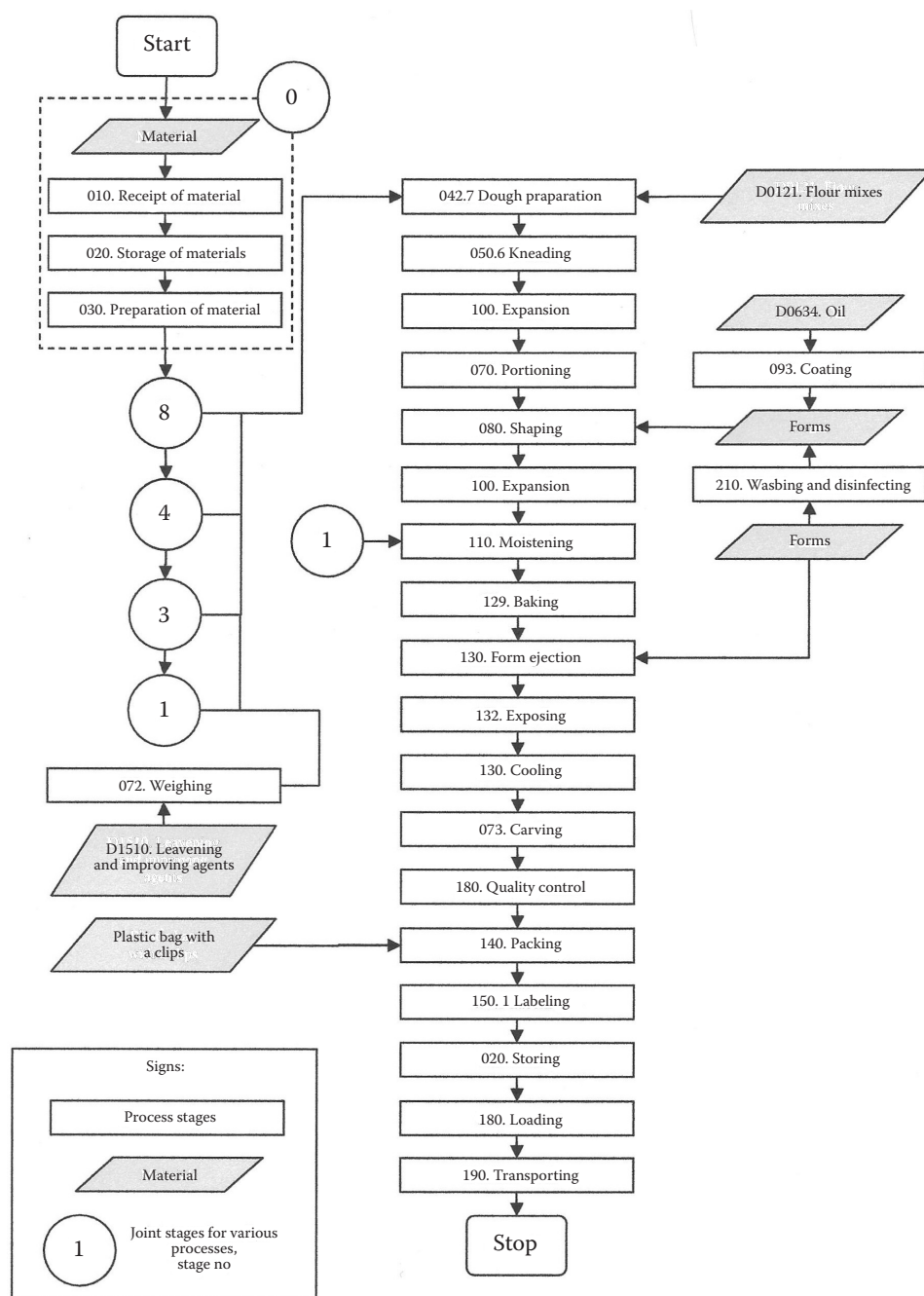


Figure 2. A simplified diagram outlining rye bread technological production process

Alternative research methods

FMEA method. It is a method a standardization deliverable was developed for (IEC 812). The method (Figure 3) revolves around establishing causes behind defects of the product, raw material, or production stage. The probability of the emergence of a failure constitutes the measure of the stages' significance (Risk Priority Number- RPN). The index is calculated as the mathematical product of the severity (S)

of the potential cause, likelihood of the occurrence of the defect or hazard (O) and the possibility of detection (D). Each of the individual elements is ascribed weight ranging from 0 to 10. The final score constitutes a number in the range between 0–1000. Events of the highest score pose the greatest hazards for the technological process, thus for the product itself. A premise is made that critical points are reflected in 3–5 stages or analyzed failures (hazards) with the highest RPN (SCIPIONI 2002).

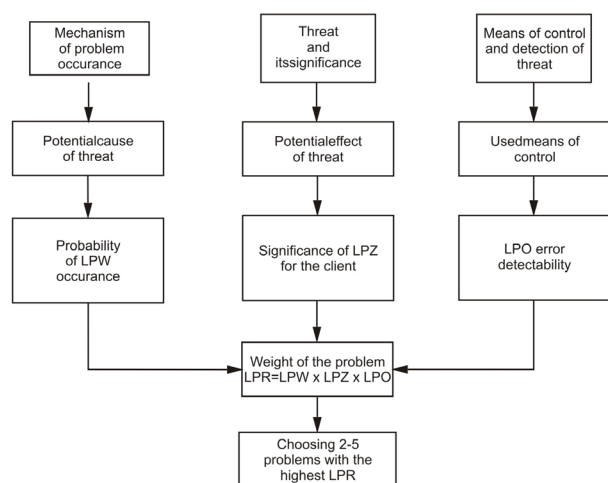


Figure 3. FMEA method diagram

Based upon FMEA, it was observed that the receipt of raw materials (Z1 and Z3) and baking (W3) constitute critical points (both scored RPN of 1000). A further RPN of 900 was calculated for egg cracking (Z1 and Z3), and 810 for the receipt of materials into production.

Pareto chart. Lorentz Pareto analysis is a type of chart containing both 'bars' and a line chart. The bars show the values in descending order, and the line graph shows the accumulated sums of each category from left to right. The diagram was named after Vilfred Pareto. The left vertical axis usually contains observation frequencies, but it can also represent a cost or other important measure. The right vertical axis represents the cumulative percentage of all observations, the total cost, or the sum of the selected measure. Because the causes are sorted in descending order, this function is concave. The goal is to show the most significant of (usually) large number of factors. In quality control, the Pareto diagram usually represents the most common causes of damage, the most common types, the most common reasons for complaints, etc. The method requires the possession of quantitative data regarding the hitherto course of the process. In the evaluated case, the data encompassed the period 100 000 loaves of bread were produced in. Like in previous approaches, the development of the technological process chart is a prerequisite in this case as well. Subsequently, potential hazards and/or product defects emerging in the assessed period are described. Five defects (W1-W5) and three hazards (Z1-Z3) were identified in the bakery. Figure 4 outlines the quantitative sheet of the registered events.

In case of baker's goods, a joint analysis of hazards present in the production process and prod-

uct defects may seem somewhat faulty. This results from the sequence and significance of the event for the product. In general, product defects constitute non-removable features of the product. Hazards, on the other hand, are associated with the production process itself, thus the majority of these ought to be eliminated when implementing the Good Hygienic Practice and Good Manufacturing Practice. The remaining hazards ought to be controlled and maintained at a non-hazardous level. The issue of which events are attached to the defined categories is significant. The quality assessment on the basis of the Pareto chart was conducted by calculating the percentage share of individual events (KARDAS 2017; TIAN 2017). Afterwards, results were presented in the chart (Figure 5).

The analysis of Figure 5 indicates that the emergence of defective products is the key problem of the studied bakery. Hazards associated with the technological process bear less significance. Three main defects W3, W1 and W5 result in the emergence of 66.8% of defective products. The fact that W1 constitutes 38% of the total number of failures is noteworthy. Such a high value necessitates an in-depth analysis associated with causes behind the emergence of defective crust. In addition, the bakery is characterized by a relatively low number of hazards out of which Z1 constitutes 13% of the total number of registered

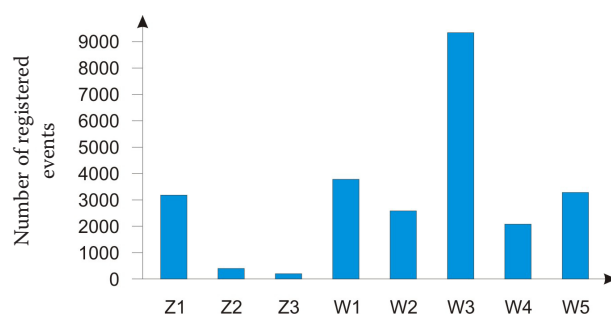


Figure 4. Hazards and defects registered in the production process

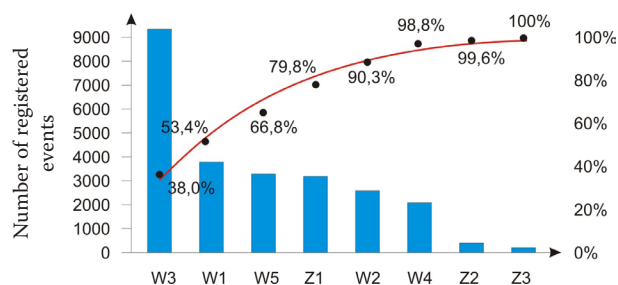


Figure 5. Pareto chart

cases. A large discrepancy between Z1, Z2 and Z3 may stem from a certain 'leakiness' of the existing quality system, i.e. HACCP.

Quantitative indexes. In order to evaluate production quality before the mandatory HACCP quality control system was implemented, the owner intuitively applied the quantitative quality index. The index is defined as a ratio of the actual process output to the targeted value. The literature of the subject defines the index as the product capability index (OBORSKI *et al.* 2017). The owner of the bakery aspires to achieve 3 or less defective loaves among 50 000 final products. Therefore, it means that the owner targets $C_p = 1.33$ (share of defects approx. 0.006%). This value reflects the output of large series in long-term perspective. The value meets the Japanese standard adopted in the 1980s in the automotive sector. The C_p proves the owner aspires to achieve extremely high output quality. Based upon the author's professional experience, it can be estimated that slight defects (irrelevant for consumers) in the bakery industry emerge in approx. 1 out of 500 items. On the other hand, as far as the serious, consumer relevant defects are concerned, a defective item emerges in between 1000 and 2000 final products. Clearly, the type of product is significant in the present case. The data discussed above are approximate and, based upon the Pareto chart (Figure 5), do not reflect the situation of the bakery well. Undeniably, it stems from a very general and ambiguous description of defects and hazards registered in the bakery. To conclude, the number of failures in the process is too great when compared with the owner's targeted value. As a consequence, the process is currently under further analysis.

Ishikawa diagram. Baking process consists of individual stages and technological operations (Figure 6), which, when operating properly, result in the manufacture of high quality product. Apart from the technology directly associated with manufacturing, the impact of areas surrounding the production is significant for product quality (Figure 7). A separate Ishikawa diagram was composed for each identified defect and each identified hazard in association with areas impacting the production process (Figure 8).

The Isikawa chart (due to its characteristic appearance called the fish bone chart) allows to identify the reasons for actual or potential failures of various types of projects. For this reason, this method is also called a cause-and-effect diagram. The scope of application of this method was initially limited only

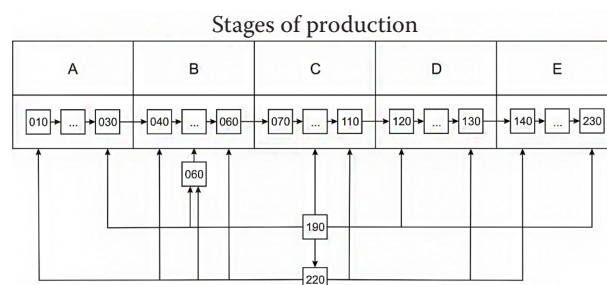


Figure 6. Outline of technological processes and operations

010 – receipt of material; 020 – materials storage; 030 – materials preparation; 040 – dosing; 050 – mixing; 060 – fermenting; 070 – portioning; 080 – forming; 090 – adding extras; 100 – expansion; 110 – preparation for baking; 120 – baking; 130 – cooling; 140 – carving; 150 – packing; 160 – preservation; 170 – labeling; 180 – storing; 190 – quality control; 200 – loading; 210 – transporting; 220 – washing and disinfecting; 230 – displaying

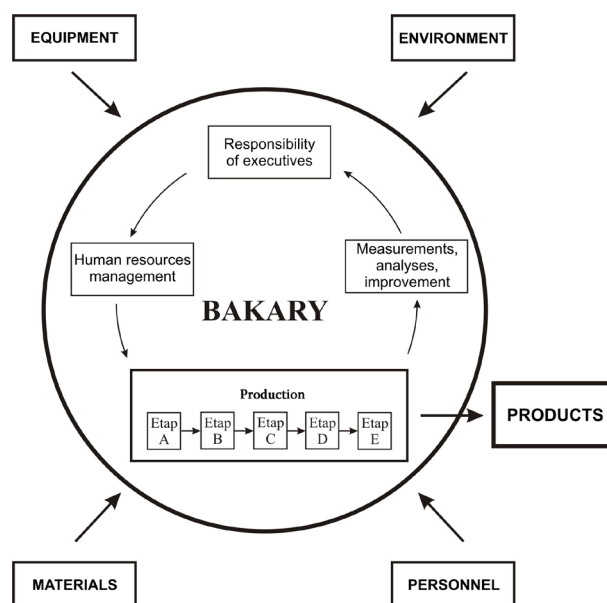


Figure 7. Processes significant from the perspective of quality assurance systems

to industry, but in a short time it proved to be useful in many other areas. The graph consists of arrows with descriptions, combining in such a way that the main arrow indicates the effect, i.e. a description of the failure that is being tested. The shape resembles a fish bone, where: the head of a fish means a problem to be solved, the backbone of a fish is a group of causes that can affect the appearance of a problem, and define the specific causes belonging to a given group of causes.

The categories of causes shown in Figure 8 are usually chosen from the set:

- (1) Personnel – including qualifications, job satisfaction, habits or seniority,
- (2) Environment – containing elements of the work environment,
- (3) Management – including the organizational structure, work organization,
- (4) Material – containing input materials, substitutes, semi-finished products,
- (5) Equipment including tools, modernity, performance, precision, durability, safety and working conditions.

You can also use other categories (e.g. procedures, equipment, materials, information and people) depending on the field in which the chart is used. Each category of causes is expanded with further detailed causes. If necessary, a sub-carrier is also included. Expansion of the graph ends when the phenomenon is fully identified.

The diagram (Figure 8) indicates that human factor plays a significant role in each area of baker's goods production. Disadvantageous events result from noncompliance with instructions and low awareness level—lack of trainings, deviations from procedures, lack of supervision, etc.

Whys method. One of the methods applied in searching for causes of original hazards and defects associated with the human factor is the 5 (CHLEBUS & WERBIŃSKA-WOJCIECHOWSKA 2017). Whys approach. The method utilizes a series of five questions. All these questions begin with the word 'why', hence the name of the approach. Usually, the initial question is very general, and each subsequent one specifies the previously given answer. Figure 9 outlines an example of exploring causes with the application of the method.

The method enabled the critical cause behind the emergence of defective products to be detected. The effectiveness of the method depends largely upon maintaining the standard of questions asked. The following constitute the main principles of the method:

- (1) Right and comprehensible formulation and definition of the problem,
- (2) cause-effect logic and differentiation between causes (hazards) and symptoms (defects) must be present,
- (3) the analysis ought to be conducted on a step-by-step basis without jumping to seemingly obvious conclusions,

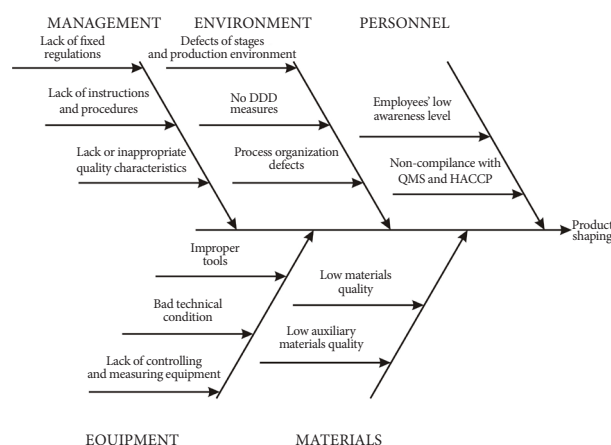


Figure 8. Example Ishikawa (DROZD & BIELSKI 2017) diagram for W1 defect (shape defect)

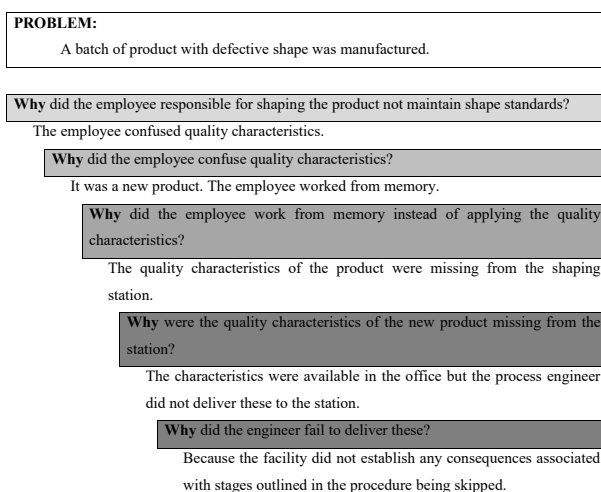


Figure 9. Whys algorithm for W1 defect (shape defect)

(4) causes ought to be sought for in processes instead of people,

(5) 'why' questions ought to be posed until the root cause, i.e. one when once eliminated will eradicate the problem altogether, is established.

CONCLUSIONS

The analysis of baker's goods' quality on the basis of HACCP conforms with legal regulations but does not considerably contribute to quality improvements. Each of the discussed methods boosts product quality. The most significant reasons behind the emergence of inconsistencies were associated with employees' non-compliance with standards and regulations. Results of FMEA confirm the significance of the listed causes behind inconsistencies emerging in the pro-

cess. The quantitative picture of the problem is well described in the Pareto chart. The chart indicates that approx. 14% of causes produce 67% of effects. The Ishikawa diagram represents cause-effect relationships in the process and graphically present significant causes. The 5 Whys method enables the root causes of an issue to be established. The remaining methods play a supplementary function in the studied company as far as the product quality is concerned. The analyses facilitated the establishment of a preventive action plan in relation to a narrow group of specifically selected causes.

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Received: 2018–02–15

Accepted after corrections: 2019–01–30

Published online: 2019–02–18