SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 162

THE IDENTIFICATION OF QUALITY CONTROL METHODS USED IN THE PACKAGING PRODUCTION PROCESS

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Purpose: The aim of the article is to identify the quality control methods used in companies producing packaging and to obtain knowledge of the scope of the use of optical sensors.
Design/methodology/approach: Enterprises located in Poland in the Greater Poland Voivodeship, producing paper, board, corrugated and plastic packaging. The triangulation strategy was used in the study in which Computer Assisted Web Interview (CATI), Individual In-depth Interviews (IDIs), and Case Study were applied. The subject of research was the identification of quality control methods at individual stages of packaging production and the responsibility for carrying it out, as well as the method of presenting the control results. In addition, the use of optical sensors for quality control was assessed.
Findings: Digitalization of manufacturing leading to the Industry 4.0 concept provides novel tools for quality control and data storing. It enables real-time data collection and processing for even better even better management of the production process and quality control. However, the concept of Industry 4.0 (including Big Data Analysis, Internet of Things, Artificial Intelligence, Neural Networks) is not new, still many companies find it difficult to implement it and benefit from its capabilities. The surveyed packaging companies are characterized by low use of the possibilities related to the use of more advanced methods of product quality control at individual stages of the production process. The potential for improvement is the area of process and product control through the use of optical sensors/actuators, etc., and the form of keeping records of the product quality checks carried out.
Research limitations/implications: The results of this research are not representative, but they encourage the authors to carry out a broader and more in-depth analysis of the research subject on a national scale.
Practical implications: Research indicates the need to improve the quality control process in the production of packaging and a wider use of modern solutions with the use of optical sensors.
Originality/value: An article can be an element influencing the management to better select quality control methods at various stages of the production process.

Keywords: quality control, packaging, control methods, optical sensors, Internet of Things (IoT).

Category of the paper: Research paper.

1. Introduction

Packing is one of the necessary operations in almost every production process (Wolniak, Zadura, 2012), most of the manufactured products go to the market in packaged form. Packaging is a product made of any type of material, intended for the storage, protection, transport, delivery and presentation of goods, used by moving from raw material to processed product, and so from producer to user or consumer (PN-EN ISO 14182:2005). Packaging is made of various raw materials and is still subject to innovation. Taking into account the criterion of the raw material from which the packaging is made, packaging made of paper, plastic, metal and glass is distinguished (Lisińska-Kuśnierz, 2005, pp. 9-10).

Due to the fact, that the packaging is used in various ways, they can be grouped in three types/levels:

- primary packaging (primary, unit), includes materials in direct contact with the product, it contains the product, therefor it's vital for ensuring the high quality of product.
- secondary packaging (additional, collective) is used for grouping primary packaging and facilitating their transport as well as display in retail locations.
- tertiary (transport) packaging is used for protection and shipment in the distribution process (e.g. baskets, pallets, boxes) (Leszczyński, Żbikowska, 2016, pp. 11-12).

Packaging should have the following functions:

1) protection of the product during storage, transport and use, as well as, protection of the environment against harmful effects of the product,
2) enabling and facilitating: production, wholesale and retail trade and use of products,
3) information, *inter alia*, about: the raw material composition of the product, its calorific value, method of preparation for consumption and the date of expiry or use-by date,
4) the product packaging should be attractive in terms of graphics and colors, i.e. arouse the interest of a potential consumer (Sykut, Kowalik, Droździel, 2013; Lee, Rahman, 2014; Ghaani et al., 2016).

Food packaging plays an important role because of its impact on safety and quality of the packed product. Packaging is an integral part of packed food; it serves as a protective barrier and enables the desired quality, freshness and durability to be maintained. Safe packaging should be characterized primarily by an appropriate sanitary and hygienic condition, not posing any threat to the packed food product, but should also ensure the safe use of the packaging (Szumicka, Górna, 2018; Wang, Wu, Cao, 2019).

Packaging manufacturers are responsible for controlling the production process, starting from the preparation stage of the production process, through its stages, ending with the release of finished products. The quality of packaging is determined by many factors, including quality of raw materials, materials and tools used (e.g. paints, printing base, printing forms, dies, adhesives), selection of the appropriate technology, knowledge and experience of personnel, machines and devices, hygiene in the plant, process and product control, documentation of activities (Winkowska, Winkowski, 2018). Quality control is essential for improving any manufacturing process. It encourages quality consciousness among workers, enables a more efficient utilization of resources and results in products of better quality at reduced production costs (Tusar et al., 2017). Product inspection should be strictly planned as to its place and time, method of conducting and criteria for accepting, rejecting, repairing the product and the persons responsible for carrying it out. Provisions confirming the fact of carrying out the control and its results, which confirm whether or not the specified requirements have been met, should be specified. Product monitoring is not only about measuring a specific physical property, but also about visual evaluation. Before the product is passed on to further processing steps and ultimately the customer, it must be ensured that the product has passed the inspection. Depending on the specificity of activities, it may be advisable to carry out an inter-operational and final control (Winkowska, Winkowski, 2018).

Depending on the intended use of the packaging (including whether the packages are for direct and indirect contact with the product) and customer requirements, defects are classified into critical defects, which make the use of the packaging dangerous, major defects and minor defects (slight deviations, minor or minor deviations imperceptible to the customer). The manufacturer, based on their own knowledge and experience, in combination with customer requirements, develops their own classification of quality defects and develops control plans, which are used by employees responsible for quality control in the company (Szumicka, 2021). The types of quality defects will vary depending on the type of raw material used for the production of packaging and the processing method - e.g. printing, lamination, etc. According to Regulation (EC) No. 178/2002 establishing the general principles and requirements of food law and establishing procedures in the field of food safety, packaging producers as participants in the food chain must identify, eliminate or limit safety-related hazards (Table 1). Food packaging can retard product deterioration, retain the beneficial effects of processing, extend shelf-life, and maintain or increase the quality and safety of food. In doing so, packaging provides protection from 3 major classes of external influences: chemical, biological, and physical (Marsh, Bugusu, 2007, pp. 39).

Table 1.
Types of hazards in the production of food packaging

Hazards	Type of Raw Material			
	Paper	**Plastic**	**Glass**	**Metal**
Physical	Foreign bodies: glass, metal, wood, plastics, hair, jewelry components, sand and stones, pests and pest droppings			
Biological	bacteria, viruses, toxins, fungi			
Chemical	heavy metals, mineral oils, formaldehyde, PAA, Pentachlorophenol (PCP)	heavy metals, mineral oils, phthalates, formaldehyde, Primary Aromatic Amines (PAA)	cadmium, lead	metals, Bisphenol A (BPA)
Quality defects	creases, stains, scratches, cracks, leaks, deformations, color saturation, illegible information, print registration		improper stress relief, gas bubbles, scratches, overburden, inhomogeneous thickness, improper holes, notched edges, improper bonding of the body and the bottom	cracks, leaks, defects in the quality of the paint coating, deformations, sharp edges, nicks, bad formation of the flange, low strength of the weld, no rubber gasket

Source: (Emblem, Emblem, 2012; Caruso et al., 2017; Roohi et al. 2018, Ščetar, Barukčić, Kurek, 2019; Szumicka 2021).

Modern technological solutions such as intelligent optical sensors are contributing to the development of a new era of optimization of production processes (IoT in the Polish economy, 2019). Thanks to them, the quality of products and the quality of the production process can be monitored in accordance with the concept of Industry 4.0. The transformation to Industry 4.0 is driven by the demand for shorter delivery times, more efficient and automated processes, higher quality and customized products. Key technologies of Industry 4.0 are among others Cyber Physical Systems (CPS), Internet of Things (IoT), Smart Factories, Embedded Systems, sensors and actuators, Big Data, Cloud Manufacturing and Computing, Radio Frequency Identification (RFID), Automation, Autonomous Robots, Additive Manufacturing, Virtual Reality, Augmented Reality, Data Mining, Advanced/Smart Materials, Artificial Intelligence (AI), Machine Learning (ML), Cyber Security (Müller, Schmid, 2019; Demir, Testa, 2020; Wójcicki et al., 2022).

2. Method

Research has been conducted in 2021 and has been divided into two major parts – theoretical part and empirical part. The results of theoretical part have been published in the article titled Internet of Things in Industry: Research Profiling, Application, Challenges and Opportunities (Wójcicki et al., 2022). The empirical part was conducted with the application of triangulation

strategy. The triangulation strategy consist in combining various methods while examining one research problem aiming to increase the amount of collected knowledge and the value of the data. The data was collected using the combination of three methods: Computer Assisted Web Interview (CATI), Individual In-depth Interviews (IDIs), and Case Study.

Data presented in this research paper are based on the results of the first stage of empirical study. Quantitative data has been gathered based on a survey questionnaire. CATI (Computer Assisted Telephone Interview) has been used as a data collection technique. CATI is an Internet surveying technique in which the interviewee follows a script provided in a website or by telephone. The research population consisted of 132 enterprises located in Poland in the Greater Poland Voivodeship and classified under the following codes of the Polish Classification of Activities (PKD):

- 17.21.Z Manufacture of corrugated and corrugated cardboard as well as paper and cardboard packaging.
- 22.22.Z Production of plastic packaging.

68 enterprises took part in the study, which constitutes 51% of the surveyed population. Telephone interviews were conducted only with employees at selected positions within the organizations and competent to provide information on the subject matter (company owners, quality directors or managers, production directors or managers, and technologists). The survey questionnaire contained 17 questions related to quality control methods and techniques, the use of optical sensors, application of systems and Industrial Internet of Things (IIoT).

3. Results and discussion

Among the surveyed enterprises, the largest percentage was constituted by enterprises producing plastic packaging (44.1%), while the smallest percentage was constituted by enterprises producing multilayer packaging using three raw material groups - plastics, paper and aluminum (17,6%) (Figure 1).

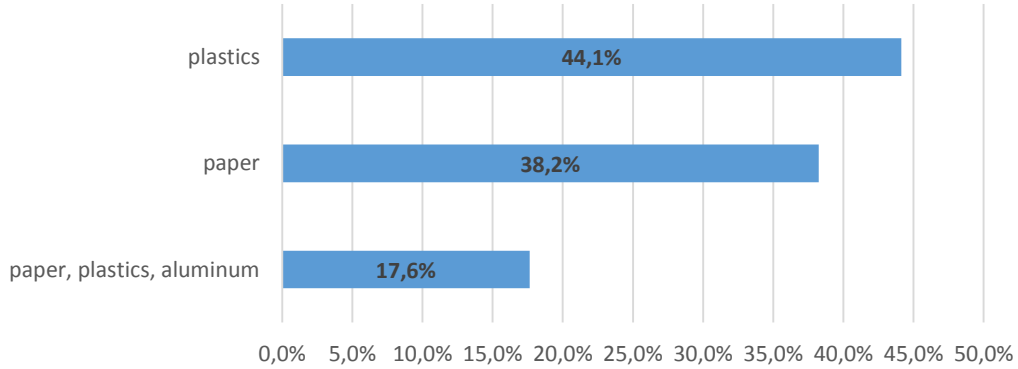

Figure 1. The structure of enterprises in terms of the material of manufactured packaging.

Source: Authors' own research.

Almost 59% of enterprises use packaging printing in the production process (Figure 2).

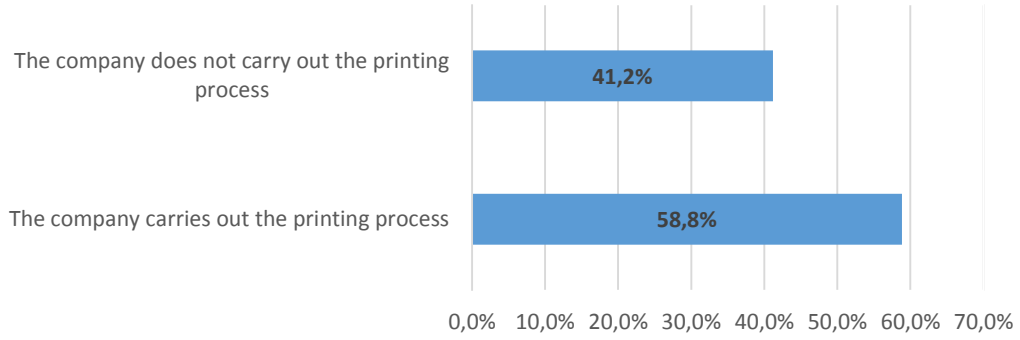

Figure 2. The structure of enterprises in terms of the implementation of the printing process.
Source: Authors' own research.

Most of the surveyed companies (over 50%) declared the production of packaging for contact with food (Figure 3).

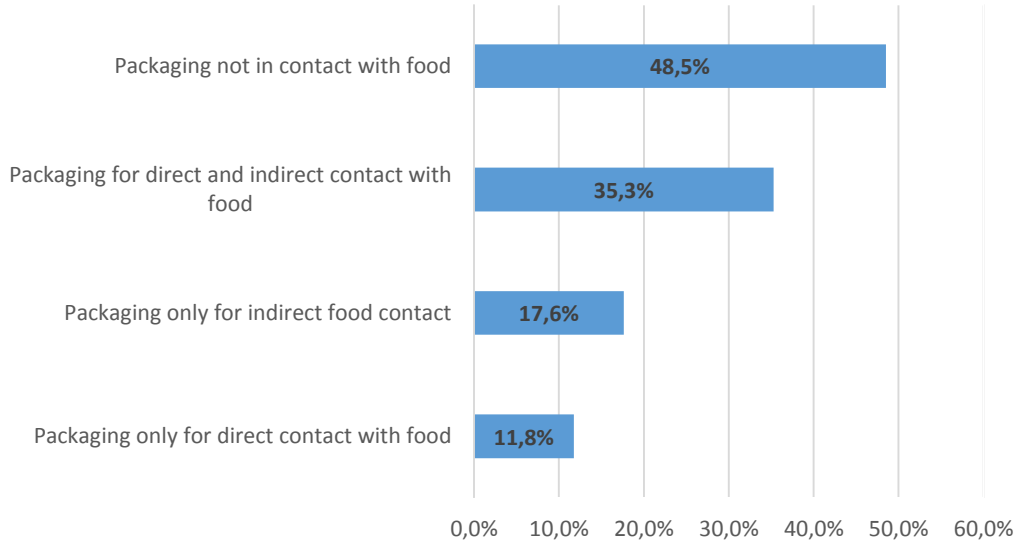

Figure 3. Purpose of the manufactured packaging.
Source: Authors' own research.

35.3% of the surveyed companies declared the production of packaging for direct and indirect contact with food, and 17.6% manufacture packaging only for indirect contact with food. On the other hand, 11.8% of enterprises indicated that they manufacture packaging intended for direct contact with food. In general, companies that produce packaging for direct or indirect contact with food and other hygienically sensitive products (e.g. cosmetics) are forced to comply with legal requirements regarding the supervision of the safety of these packaging, which results in the need to conduct tests of manufactured products and implement effective product quality control and the production process.

The analyzed enterprises declared that they have a certified management system (Figure 4).

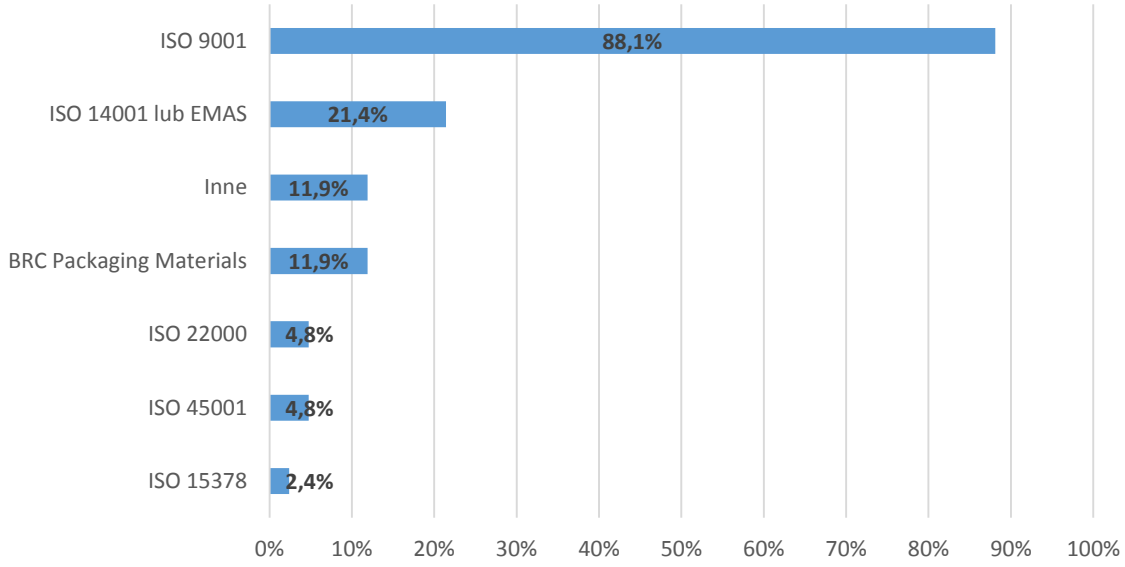

Figure 4. Certified management systems implemented in the enterprise.
Source: Authors' own research.

Most, i.e. almost 90% of enterprises declared having a quality management system in accordance with the requirements of ISO 9001 "Quality Management Systems – Requirements", while the least of the surveyed enterprises declared having a certified quality management system in accordance with ISO 15378 "Primary packaging materials for medicinal products — Particular requirements for the application of ISO 9001:2015, with reference to good manufacturing practice (GMP)", which is understandable, as this standard applies to a narrow group of enterprises producing direct packaging materials for medicinal products.

As a rule, the interviews were conducted only with people competent to provide information on the subject matter studied, they were company owners, directors or quality managers, production directors or managers, and technologists.

3.1. Methods of raw material quality control

Raw material quality control is a key element in any manufacturing company. The use of appropriate control methods allows for the avoidance of future problems with the raw material during processing operations or the use of an already finished product. The representatives of the surveyed companies were asked about the methods of quality control used at this stage of the production process, who carries out the control and how its results are recorded. The respondents had a choice of 8 most adequate control methods and the possibility to select the option "other". However, despite indicating the option "other", they did not specify its type. 88% of respondents indicated the use of organoleptic evaluation at the stage of raw material quality verification. In most enterprises (57%) it is carried out by line employees, which proves that employees are empowered to perform tasks in this area. On the other hand, almost 100% of the surveyed companies indicated that they verify the quality specifications for a given batch

of raw material and declarations of conformity, as well as examine for example the grammage and thickness. Although, spectroscopic (68%) and chromatographic (60%) tests are carried out in the surveyed enterprises, still most common are verification of documentation regarding quality specification (94%), verification of declaration of conformity (93%), grammage control (93%), thickness control (90%) and organoleptic assessment (88%) (Figure 5).

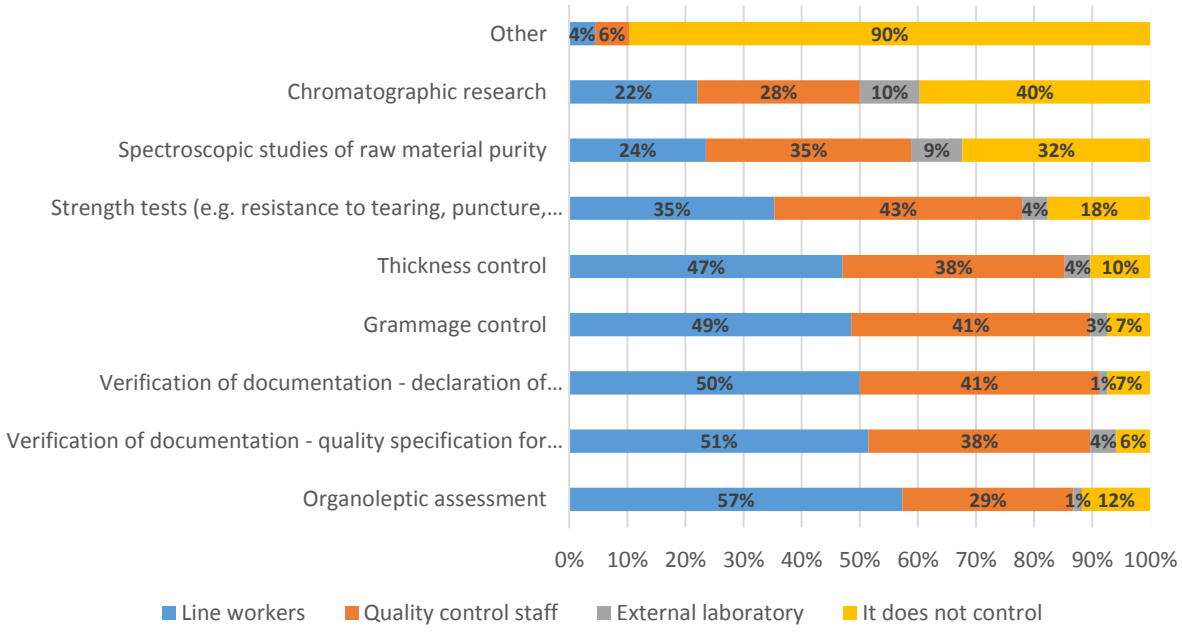

Figure 5. Methods of controlling the quality of raw materials and levels of responsibility.
Source: Authors' own research.

Line workers and quality control workers are most often responsible for the inspection of raw materials. A small percentage of tests are delegated to external laboratories. About 10% of the surveyed companies carry out chromatographic and spectroscopic tests in external laboratories and 50% and 59% respectively on site. Based on the survey, it can be concluded that more and more enterprises are equipped with equipment that allows qualified employees to carry out this type of research on site.

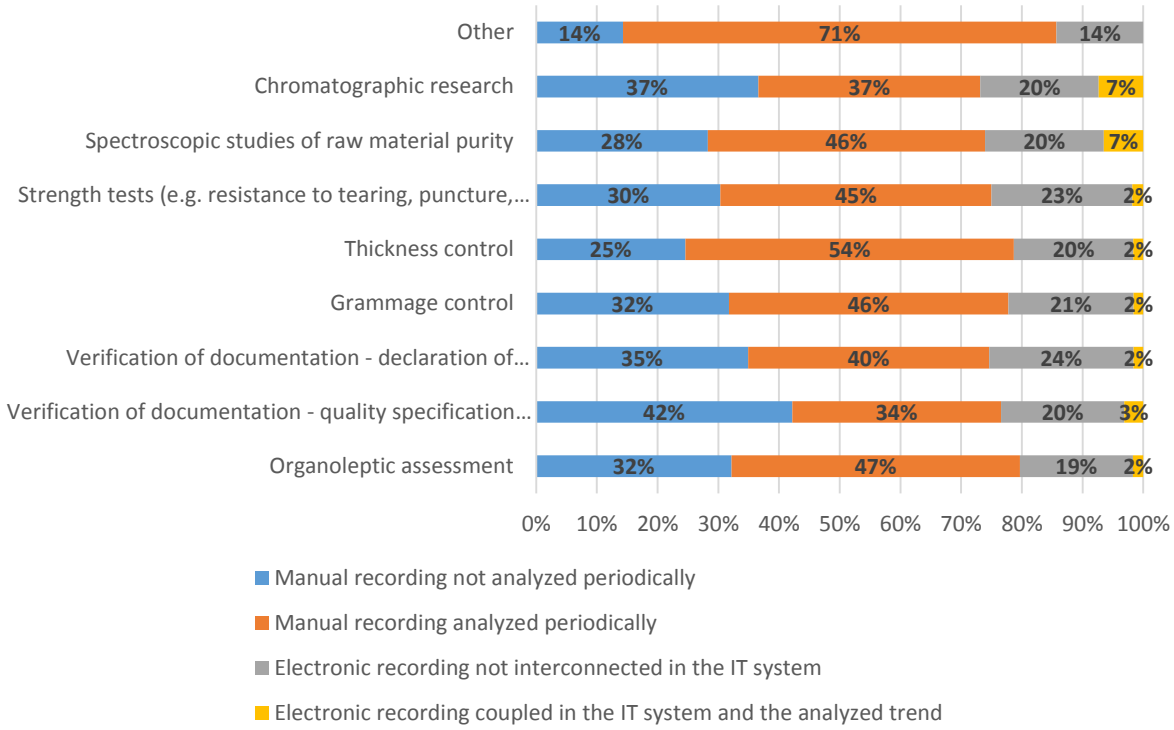

Figure 6. Measurement methods for quality control of raw materials and forms of records.
Source: Authors' own research.

The respondents were asked to indicate the form of records that are created after conducting a given raw material survey (Figure 6). The highest percentage of indications concerned the form of handwritten records, which are periodically analyzed. At the same time, a disturbingly large percentage are also manual entries, which are not subject to periodic analysis. Only 2-7% are electronic records coupled with the information technology (IT) system, thanks to which trends may be analyzed. In the era of Industry 4.0, it is disturbing that this form of recording the results of qualitative research is still uncommon among enterprises.

3.2. Product quality control during and at the end of the production process

The surveyed companies indicated which methods of product quality control they apply during the production process. The largest percentage of respondents (94%) uses visual assessment of the quality of semi-finished products in terms of compliance with color patterns (e.g. Pantone) (Figure 7). These tests are carried out in most enterprises by line employees (60%). On the other hand, the remaining tests are carried out to a comparable extent by both line employees and quality control employees. It should be presumed that the tests carried out by quality control employees will be tests verifying the correctness of tests carried out by line employees.

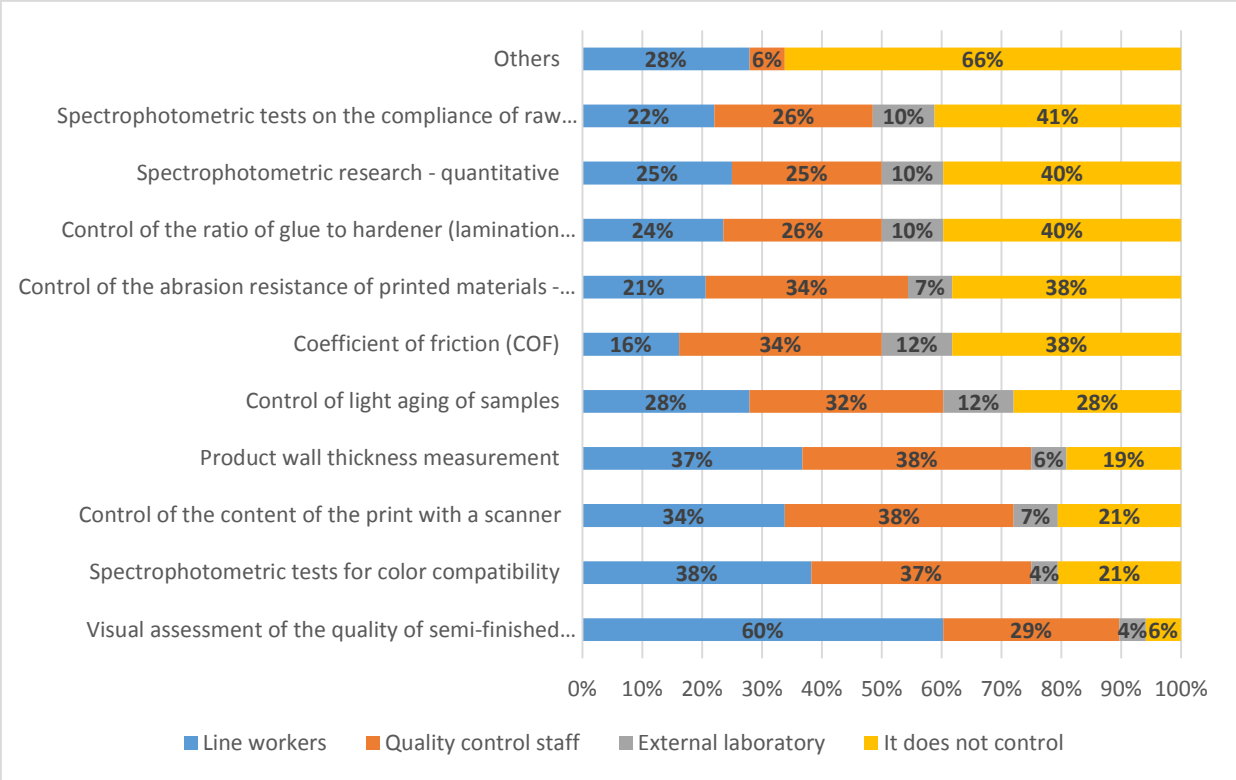

Figure 7. Verification of product quality control during the production process.

Source: Authors' own research.

The respondents were asked about the reasons for not carrying out product quality verification during the production process. The respondents mainly indicated that some of the surveys do not apply to their products, and do not have the appropriate infrastructure. Interestingly, about 20% of the respondents indicated that they did not carry out such tests, because customers do not require them to do so. It can be concluded that customer requirements are of key importance for the quality control methods used in the surveyed companies. Considering this, it can be assumed that this kind of activity allows for reduction of production costs.

At the end of the production process, the quality of the manufactured products is checked by 98% of the surveyed respondents through visual assessment for compliance with the finished product patterns (Figure 8). This form of control is most often performed by line workers (66%), which proves that product control is incorporated into the production line. There are no significant differences in the distribution of responsibilities for the performance of the remaining controls. It can only be pointed out that a relatively small percentage of tests is outsourced to external laboratories, which is often associated with high costs for enterprises, hence it is more advantageous to carry out these indicated forms of product control on-site at the plant.

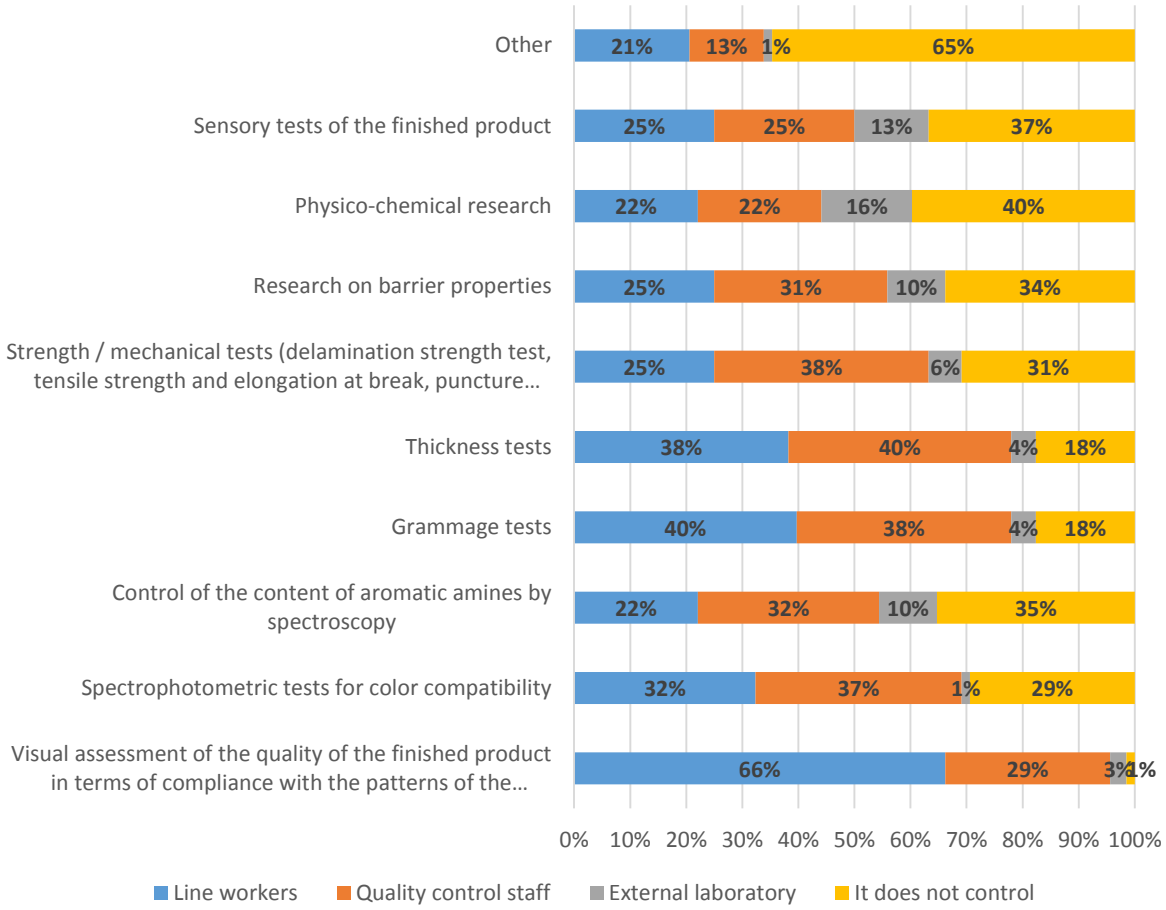

Figure 8. Verification of product quality control at the end of the production process.
Source: Authors' own research.

A significant percentage of the surveyed companies do not perform, among others:

- physico-chemical tests (40%),
- sensory tests of finished products (37%),
- spectroscopic analysis of the aromatic amines content (35%),
- tests of barrier properties (34%).

Considering that the research was conducted among enterprises producing food packaging, the fact that such a percentage of respondents did not undertake research on products in the above-mentioned areas is disturbing. In order to gain knowledge about the use of optical sensors / actuators in enterprises and their use in supervising the quality of products, information was obtained from respondents, which proves that the use of this type of devices in the industry under research is still very limited (Figure 9).

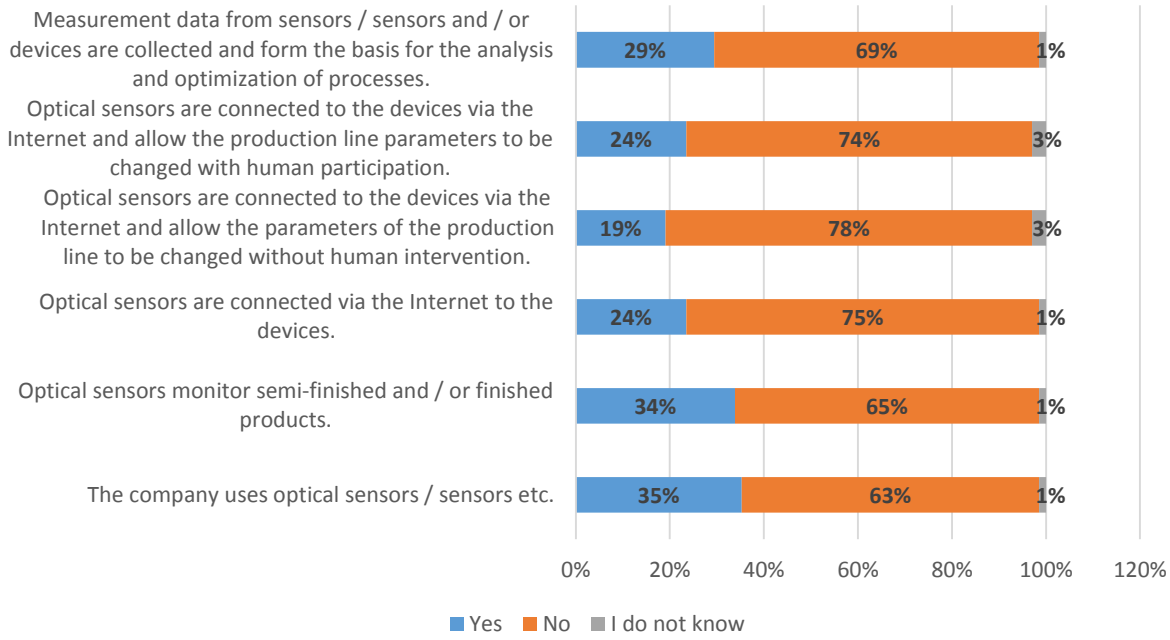

Figure 9. The use of optical sensors/actuators for product quality monitoring.

Source: Authors' own research.

Only 34% of the surveyed companies use optical sensors/sensors to monitor products, and 29% use the collected measurement data for process analysis and optimization. In turn, only 19% of the surveyed companies have optical sensors connected to devices via the Internet, which allows the parameters of the production line to be changed without human intervention. In the era of Industry 4.0, the collected data proves the still poor development of enterprises in this industry in the use of technology development. Over 60% of surveyed companies do not use any sensors for quality monitoring. This suggests that this process is being performed manually. Only a small percentage of companies (1-3%) is not aware of the use of optical sensors in their company.

4. Conclusions

The surveyed companies indicated that tests were carried out at various stages of the production process, from sensory tests, documentation verification to the use of more advanced tests. The highest percentage of respondents indicated the use of a manual entry form from the conducted quality inspections, and a negligible percentage of respondents indicated the use of electronically coupled entries to an IT system. In the era of Industry 4.0, it is disturbing that this form of recording the results of qualitative research is still not uncommon among enterprises. Moreover, the fact that over 60% of companies do not use any sensors for quality monitoring, can lead to an assumption that respondents are either not aware of their existence at the

production lines or in fact don't have them. However, it's doubtful as more and more production lines are already equipped with different sensors monitoring different parameters during production process.

Over 58% of the surveyed companies declared that they use packaging printing, while at the same time 37-40% declared that they did not carry out physico-chemical and sensory tests. Printed packaging carries a number of threats to packaged food. Lack of control in the indicated areas means that we are dealing with a high risk of chemical contamination. Printed packaging is most often laminated, and 35% of the surveyed companies do not control the content of aromatic amines. At the same time, it should be noted that during the interviews, the respondents often indicated the lack of customer requirements as the reason for not carrying out specific testing. Therefore, it can be concluded that customers are the factor influencing the application of certain methods of product control by packaging producers.

A small percentage of the surveyed companies had the implemented BRC Packaging Materials standard (11.9%), which probably also influenced the results of the research in the scope of controls carried out in the packaging production process. The requirements of this standard impose the need to control the process and the product, therefore the production plant must prove that it applies reliable control methods confirming the quality and safety of the manufactured products.

Line workers are engaged in product quality control in the surveyed companies, and most often they perform visual assessments. It is still possible to observe a significant proportion of employees of quality control departments in the performance of product tests at individual stages of the production process. Out of this group, a small percentage of the research is commissioned to external laboratories, which is probably related to the lack of customer requirement and high costs, which can still be a barrier to undertaking this type of research.

The conducted research showed little use of optical sensors / actuators etc. for product monitoring in the companies that did perform analysis. Thus, it can be indicated that the use of optical sensors/actuators is an opportunity for improvement for enterprises operating in this industry.

Acknowledgements

„The project financed within the Regional Initiative for Excellence programme of the Minister of Education and Science of Poland, years 2019-2023, grant no. 004/RID/2018/19, financing 3,000,000 PLN".

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