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INNOVATIONS IMPLEMENTED IN THE TECHNOLOGICAL PROCESS OF BREAD PRODUCTION AS A FACTOR IMPROVING THE QUALITY OF THIS PRODUCT

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The aim of this article is to determine the impact that innovations implemented in the technological process have on improving the quality of bread, based on research conducted in bakeries in the Pomeranian Province in 2020-2023. Bread quality results from many factors, mainly in the technological process. One of these factors is innovation.

There are no publications in the subject literature concerning the impact of innovations implemented in the technological process on improving the quality of bread.

The scope of the article is restricted to the technological process, which has been isolated for the purposes of research and modelling. The 'Introduction' is followed by a presentation of the 'Research methodology for improving the quality of bread in the technological process as a result of the implementation of innovations'. It should be noted that in a competitive economy, monographic research is dependent on the consent of business owners. In this situation, the established research directions were the subject of cooperation with companies in the baking industry. However, these companies did not agree, for example, to make *ex ante* data available.

The research was conducted in two directions, i.e.:

1. The expected improvement in bread quality after the implementation of innovations in the technological process (automated and robotised technological lines and specialised machines, mainly automated) was determined.
2. Surveys were conducted on the impact of the implemented innovations on the determinants of bread quality in the technological process. The article presents the results of these studies in the form of structural distribution series together with a 'model of the impact of innovation in the technological process on the determinants of bread quality'.

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Next, a comparison was made between the expected improvement in bread quality in the technological process and that perceived by the respondents (p. 5). The article concludes with a 'Discussion' and 'Conclusions'.

Keywords: technological process, improvement of bread quality, quality determinants in the bread technological process

1. INTRODUCTION

The primary component of a Polish person's diet is bread; as many as 98% of Poland's inhabitants declare that they consume bread daily. When approached rationally, bread can play an invaluable role as a regulator of the human digestive system and serve as a significant source of the body's daily energy requirements (Van der Spiegel, 2005).

Bread, in addition to its nutritional functions, can also serve pro-health purposes, and it is precisely this kind of product that the modern consumer is increasingly interested in. The popularity of healthy lifestyles is driving consumer interest in whole grain bread, bread with added seeds, products with reduced salt content, high-protein variants, and those with specialized compositions such as gluten-free, lactose-free, or sugar-free options (Adams, Moss, 2008). For this reason, the primary concern of bread producers should be to ensure the high quality of their products.

Despite various studies on bread quality, the issue of factors influencing the quality of this product in the technological process has not been sufficiently researched. In publications by Polish authors, these factors are presented in a fragmentary manner. Only in a 2002 collective work for bakers entitled *Baking – recipes, standards, advice, and legal regulations* was an attempt made to present the factors that influence bread quality in the technological process, without any research indicators in this area. Since then, there have been changes in the baking industry. These include consumption patterns, and artisan bakeries being transformed into automated and robotised ones. Moreover, no publications exist in the subject literature, including ones on innovation's impact on improving bread quality.

Based on the literature and the authors' observations drawn from interactions with bakery enterprises, three groups of quality determinants in the bread-related technological process have been identified[3]:

– raw material factors (quality of raw materials used, properly defined efficiency standards for bread, recipes),

[3] In this article, as in the literature on the subject, the terms 'factors shaping the quality of bread', 'factors influencing the quality of bread' and 'determinants of bread quality' will be used interchangeably.

- technological factors (selection and stability of optimal process parameters, including controlled production efficiency),
- organizational and technical factors (hygiene and sanitary conditions, reliability of machines, employee qualifications, innovations).

This article analyses one of the factors, i.e. innovations in the technological process of making bread. However, innovations' impact on bread quality in the technological process cannot be considered in isolation from other factors shaping quality, as all factors constitute a functional whole (Drozd, 2019; Ambroziak, 2002).

2. MATERIALS AND METHODS

2.1. Research methodology concerning the improvement of bread quality in the technological process as a result of implemented innovations

A survey study compiled information from bread producers in the Pomeranian Voivodeship related to 56 innovations implemented in the bread technological process between 2020 and 2023 across 51 bakeries. These innovations were systematically categorized and divided into: automated and robotic–technological lines and machines – mainly automated. Within the category of technological lines, distinctions were made between lines for bread production (8 units), bakery product lines (5 units), frozen dough production lines (4 units), and lines involving robots (5 units). The machines, in turn, were grouped into specific categories, including silos (8 units), mixers with bowls (6 units), dough proofing chambers (6 units), baking ovens (9 units), and X-ray detectors (5 units).

Research on the innovation impact was conducted in two directions to determine how implemented technological changes improved bread quality. Based on information from questionnaires administered to bread producers, supplemented by domestic and foreign literature, as well as participant observation in bakeries, the study attempted to establish the expected improvement in bread quality in the technological process as a result of the implemented innovations.

In order to verify issues related to the influence of innovations on bread quality enhancement, additional surveys were conducted in 2023. In accordance with the recommendations of the Oslo Manual 2018 (Oslo, 2018), employees are able to assess the consequences of innovations introduced by their company. It was assumed that the improvement in bread quality in the technological process could be assessed by respondents associated with a given company. The same innovation implemented in the technological process of different companies may be perceived completely differently due to the different conditions in a given organisation.

Employees considered experts in their respective bakeries were selected according to the principles of the expert-mathematical method. According to these, a self-assessment task was carried out by each respondent. For this purpose,

a questionnaire was prepared containing a score for the expert's familiarity with the problem (up to 10 points), and an assessment of the level of influence of the argumentation source on their opinion (Zając et al., 2015). This influence assessment used 3 levels with a score from 0 to 1. The survey data sheet shows that the respondents were employed in the technology department (88.2%) and in the quality department (11.8%), and 92.2% of the respondents had more than 10 years' experience in the bakery industry. Respondents were asked to rate the impact of the innovations implemented in their company's technological process on bread quality determinants using a five-point Likert scale, ranging from 1 (lowest significance) to 5 (highest significance).

The next stage of the research involved comparing the expected quality improvements in the bread technological process resulting from the implemented innovations with those perceived by the respondents. The comparison was made within individual groups: technological lines and machines.

2.2. Determining the expected improvement in bread quality following the implementation of innovations in the technological process

The first group of implemented innovations pertained to technological lines. Specialized lines for bread and bakery production are equipped with various high-quality machines. Perfect synchronization in production line operation ensures that the baking process occurs precisely within the designated time frame (Zgodavova, 2020). Bread quality is significantly influenced by gentle "handling of the dough" without damaging its structure. The dough is consistently shaped, meets strict baking parameters, and maintains high reproducibility. Automation enables the optimization of line parameters by stimulating specific bread-making processes and identifying optimal retooling strategies in the long term (Honczarenko, 2000).

Only specialized lines are used for producing frozen dough. This dough is intended for baking bread rolls and loaves directly at the point of sale. The trend in baking bread on-site is gaining momentum among large distribution chains, restaurateurs, and even convenience stores at gas stations. The freezing process inhibits the growth of microorganisms; however, it requires precise cooling to produce high-quality dough according to established bakery standards. Moreover, frozen bread contains no preservatives or colorants but lacks natural sourdough (Oest et al., 2020). Despite its advantages and disadvantages, bread made from frozen dough remains popular due to its key feature of freshness, which consumers associate with external characteristics such as crumb, aroma, and crust (Heenan et al., 2008).

An intrinsic element of every robotized technological line is components related to occupational safety and hygiene in the form of what is called 'technological fencing' (Kaczmarek, 2008). The primary purpose of this barrier is to properly secure the entire robotic production line against accidental or unauthorized access and to prevent cross-contamination (Gania, 2016). Cross-contamination with pathogenic

agents significantly affects food safety and public health, and it is among the most common causes of foodborne illnesses. The benefits of implementing robots in technological processes are also evident in improving the reliability of machine operation within robotic systems, as robotization does not require a complete overhaul of the process but instead modifies specific tasks that constitute "bottlenecks" in the technological flow (Kaczmarek, Panasiuk, 2014). In bakeries located in the Pomeranian Voivodeship, robots are used in technological processes for loading and unloading baking ovens, palletizing and depalletizing with the use of multifunctional robots, and transport tasks servicing specific machines. Each implemented robotic system requires an individualized approach to work design and operation (Kost et al., 2013).

The innovations implemented in the bread technological process also included machines (mainly automated) that were categorized into specific groups. The silo system is responsible for storing the primary raw material, flour, which is transferred directly from specialized transport vehicles into the silos. Modern silos are equipped with a control system that includes weighing mechanisms and strain gauge sensors. Thanks to this system, the bakery maintains full control over the delivery and consumption of flour throughout the entire production cycle (Patel et al., 2022). Additionally, the installation of sifters, screens, and the airtight sealing of the tanks guarantees high quality and purity in the raw material, which is free from potential foreign objects. The introduction of a modern silo system also contributes to improved bread quality through optimal flour aeration and loosening (Kannan, Boie, 2003).

The mixer system represents another group of machines in the bread production line. Other ingredients are added to the sifted flour, such as yeast or natural sourdough, salt, sugar, and improvers, with water gradually poured in. Automated mixers are integrated with highly accurate weighing containers and a control computer, which guarantees uniformity in the raw materials used and precise recipe execution. The water that is added also maintains a predetermined temperature. These procedures enable the even combination of all dough ingredients within a specific timeframe during the processes of mixing, beating, kneading, and working the dough. Thanks to automated control, excellent dough consistency is achieved, which directly affects product quality (Sassanelli et al., 2021).

The modern dough proofing chamber is responsible for resting the dough portions, which affects proper rising. This production phase requires the appropriate temperature, air humidity, and dough proofing time. Inside the chamber, ideal conditions for yeast activity are maintained, ensuring a stable and reproducible fermentation process. Moreover, modern proofing chambers allow for precise control of air humidity and temperature, and can be adapted to suit the specific requirements of different dough types. Proper dough rising primarily influences the structure and flavour of the final product (Kotsianis et al., 2022).

The functionality and reliability of baking ovens play a crucial role in maintaining a stable temperature level, depending on the type of dough being baked (Mitelut et al., 2021). According to bakers, key bread characteristics, such as shape,

colour, elasticity, aroma, taste, and crust, depend largely on optimal baking temperature. Modern thermal oil ovens are made entirely from acid-resistant steel and are designed for intensive use. They are equipped with a control system integrated with a computer that continuously monitors the proper functioning of the equipment. The construction of thermal oil ovens ensures uniform temperature distribution across the heating plates, which guarantees even baking and consistent product quality (Nasruddin, 2013).

The operating principle of the detector is based on X-ray structural analysis. Through the use of diffraction scattering of radiation generated by ionizing radiation sources, a projection of the internal structure of the object is produced and monitored on a display screen. The X-ray detector is capable of examining both unpackaged bread and bread packaged in metallized foil, simultaneously performing weight measurement (Cafarelli et al., 2024).

Above all, the X-ray detector enables the detection of high-density foreign bodies and contaminants such as metals, glass, stones, bones, rubber, and plastics. Moreover, it automatically rejects contaminated bread and can also identify product defects such as breakage or deformation, and assess the bread's weight. Integrating an X-ray detector into the production line enhances both the health-related safety of the bread and its aesthetic qualities, such as shape and volume.

3. RESULTS

3.1. Survey research regarding of the impact of innovations implemented in the technological process on the determinants of bread quality

3.1.1. Survey research results

To analyse the impact of innovations implemented in the technological process on the determinants of bread quality, all values assigned to the Likert scale were used, representing the degree of agreement with a given statement (Robinson, 2024), namely:

1) Strongly disagree.
2) Rather not.
3) I don't know.
4) Rather agree.
5) Strongly agree.

For each group of implemented innovations, all values from the Likert scale were summed (Memmedova, Ertuna, 2024). The total number of responses indicated by the respondents was then divided by the number of responses (arithmetic mean). This can be interpreted as the average impact of innovations, within each group, on the individual factors impacting bread quality.

The study obtained 302 positive numerical assessments, corresponding to the responses "strongly agree" (62 ratings) and "rather agree" (240 ratings). These represented 77.04% of the total responses, indicating that innovations have a significant impact on the determinants of bread quality. Therefore, innovations not only influence quality but also contribute to its improvement.

The remaining 90 numerical responses constituted 22.96% of the total and corresponded to the assessments: "I don't know" (28), "rather not" (52), and "strongly disagree" (10). The ratings of "strongly disagree" specifically related to X-ray detectors, which do not affect certain quality-influencing factors, such as the establishment of bread yield standards or formulation of recipes. Nonetheless, X-ray detectors were classified as technological process innovations. Due to the increasing role of food safety in the world, they represent a reliable method for detecting foreign objects and for monitoring the internal structure of bread (Cafarelli et al., 2024).

In the subject literature, the interpretation of the Likert scale is based on average results (Jezior, 2023), namely:

- an average score from 1.0 to 2.4 indicates a negative attitude;
- a score from 2.5 to 3.4 indicates a neutral attitude;
- a score from 3.5 to 5.0 indicates a positive attitude.

According to this interpretation of Likert scale values, the average impact of all implemented technological lines (22 units) on the determinants of bread quality was 3.88 points, which means that respondents' attitudes, as expressed in their responses, should be classified as positive. Similarly, the average impact that all machines implemented in the technological process (34 units) exert on bread quality determinants amounted to 3.66 points, which also reflects a positive level of acceptance of the issue by the respondents.

When analysing the research results, it should be noted that they were relatively difficult to interpret due to the presence of 56 different types of innovations implemented in enterprises with varying technological conditions, and their impact on seven determinants of bread quality. After systematizing the innovations, the results were analysed within each group using the arithmetic mean for each group.

The first group analysed in terms of the impact of technological process innovations on bread quality determinants consisted of technological lines (for the production of bread, bakery goods and frozen dough, and lines involving robots). The greatest perceived impact on the determinants of bread quality, according to respondents, came from the installed lines for bread and bakery production. The average score of all assessments concerning the impact of bread production lines on the individual factors shaping bread quality ranged from 3.63 points (properly established bread yield standards) to 4.5 points (machine reliability). In the case of bakery production lines, the impact of innovations on bread quality determinants ranged from 3.6 points (employee qualifications) to 4.6 points (machine reliability).

The implemented lines for bread and bakery production influenced all quality determinants, with machine reliability being rated the highest. The perceived impact that specialized lines for frozen dough production have on bread quality determinants ranged from 3.0 points (properly established yield standards) to 4.5 points (machine reliability).

In the group of technological lines involving robots, respondents' evaluations were highly diverse. Robots operate within specific systems and modify only those tasks that represent "bottlenecks" in the technological process. This explains the varied influence of the installed robots on the factors that determine bread quality. Nonetheless, robots implemented in the technological process had a significant impact on machine reliability and employee qualifications, both scoring 4.4 points. The qualifications of robot operators should be high and tailored to the type of robot and its software.

A low impact of robots on raw material factors was observed, ranging from 2.2 points (properly established bread yield standards) to 3.2 points (quality of raw materials used and recipe formulation). The average score for this group was 3.66 points, indicating a positive attitude of respondents toward the issue under investigation.

The second group considered when analysing innovation's impact on bread quality determinants consisted of machines installed in the technological process, including silos, mixers with bowls, dough proofing chambers, baking ovens, and X-ray detectors.

The impact of automated silos on bread quality determinants ranged from 3.25 points (properly established bread yield standards and employee qualifications) to 4.25 points (hygienic and sanitary conditions) and 4.38 points (machine reliability).

According to respondents, mixer systems with bowls, which are mostly automated, affected bread quality factors with scores ranging from 3.33 points (properly established bread yield standards) to 4.0 points (machine reliability). The main advantage of modern mixers is their ability to achieve excellent dough consistency and to reduce mixing time. Modern dough proofing chambers (fermentation chambers) received similar ratings to mixers, ranging from 3.33 points (bread yield standards) to 4.17 points (machine reliability).

Installed baking ovens, primarily automated and thermal oil-based, received average scores, from 3.11 points (employee qualifications) to 4.44 points (machine reliability).

According to respondents, the perceived impact of X-ray detectors on the determinants of bread quality, primarily concerned the quality of raw materials used in production and hygienic-sanitary conditions. In the Pomeranian Voivodeship, detectors were installed that allow for the detection of foreign objects and bread defects (such as deformation or breakage), and which could also perform weight measurements. In contrast to other machines or technological lines, which, to varying

degrees, influenced all factors shaping bread quality, X-ray detectors were not, according to respondents, related to bread yield standards, recipe formulation, or employee qualifications. Their influence on the stability of optimal process parameters and machine reliability was also minimal. The average score was 2.77 points, indicating a neutral level of acceptance of the issue.

3.1.2. Presentation of Statistical Observation Results

Frequency distributions are a key method for presenting the results of statistical observation. A frequency distribution is a series that divides a statistical population into parts according to specific variants of a given characteristic. When this grouping is based on a qualitative characteristic, a structural distribution is created (Makać, Urbanek-Krzystosiak, 2020).

All values from the five-point Likert scale were used to construct the structural frequency distributions. Table 1 and figure 1 present a structural distribution, which is the result of grouping innovative production lines within the technological processes of bakery enterprises in the Pomeranian Voivodeship, according to the factors influencing bread quality.

Table 1. Technological lines implemented in the years 2020-2023, by factors influencing bread quality

Factors influencing bread quality	Points awarded for the evaluation implemented technological lines	
	Number	Share %
Quality of raw materials used in production	81	13.50
Properly established bread yield standards	71	11.90
Recipes (composition of raw materials)	83	13.90
Machine reliability	99	16.60
Hygienic and sanitary conditions	94	15.70
Employee qualifications	85	14.20
Selection and stability of optimal process parameters	85	14.20
Total	598	100.00

Source: authors' own elaboration.

Figure 1 presents the structural frequency distribution using an area chart.

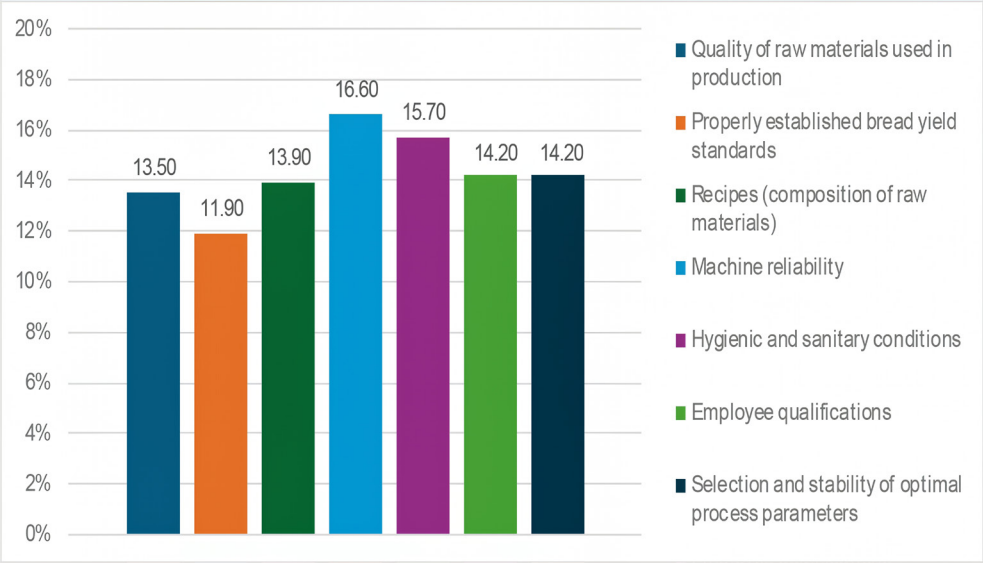

Fig. 1. Chart presenting the structural frequency distribution for technological lines by factors shaping bread quality
(authors' own elaboration)

These results of the statistical observation for automated and robotized technological lines in the bakery industry indicate that their implementation influenced all the factors that determine bread quality. Although the impact of innovations on individual quality determinants was relatively evenly distributed (ranging from 11.9% to 16.6%), the innovations had the greatest influence on machine reliability (16.6%) and hygienic and sanitary conditions (15.7%). The second group of innovations installed within the technological lines of bakery enterprises in the Pomeranian Voivodeship consisted of machines. The structural frequency distribution for these machines, according to the factors influencing bread quality, is presented in table 2 and figure 2.

Table 2. Machines implemented in the years 2020-2023, by factors influencing bread quality

Factors influencing bread quality	Points awarded for the evaluation implemented machines	
	Number	Share %
Quality of raw materials used in production	134	15.40
Properly established bread yield standards	103	11.80
Recipes (composition of raw materials)	114	13.10
Machine reliability	140	16.10
Hygienic and sanitary conditions	138	15.80
Employee qualifications	110	12.60
Selection and stability of optimal process parameters	132	15.20
Total	871	100.00

Source: authors' own elaboration.

Figure 2 presents the structural frequency distribution using a chart.

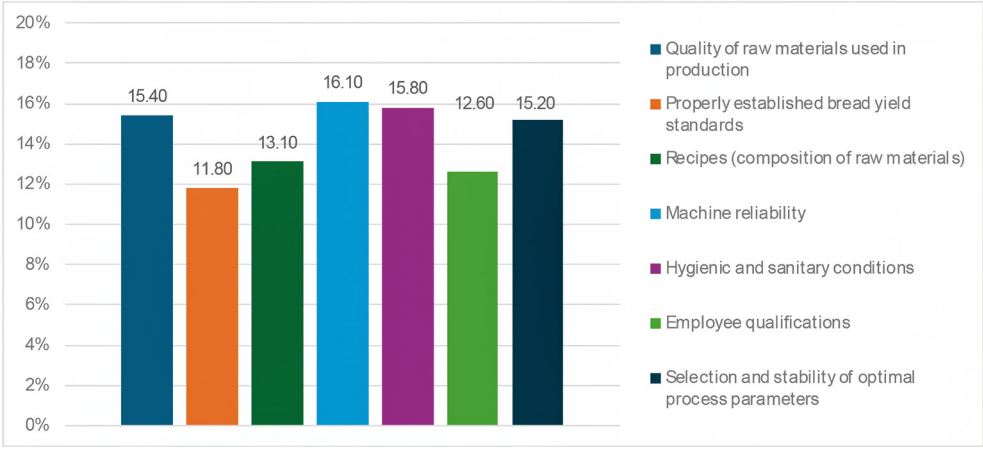

Fig. 2. Chart presenting the structural frequency distribution for machines by factors influencing bread quality (authors' own elaboration)

The innovative machines implemented in bakery enterprises influenced all the factors that determine bread quality. The greatest impact of modern machines was observed in the areas of machine reliability (16.1%) and hygienic and sanitary conditions (15.8%). The impact of the installed machines on individual bread quality determinants was relatively evenly distributed, ranging from 11.8% to 16.1%.

A positional measure of the central tendency determined by the frequency of occurrence of specific values of a feature is the mode. In a structural frequency distribution, the mode is the value of the feature with the highest frequency (Makać, Urbanek-Krzystosiak, 2020). In the case of both the implemented technological lines and the machines, the highest frequency was associated with the influence of innovations on machine reliability.

3.1.3. Model of the impact of innovations in the technological process on the determinants of bread quality

In light of the research presented here on the impact of implemented innovations in the technological process on the determinants of bread quality, a model titled *Model of the impact of innovations in the technological process on the determinants of bread quality* was developed and is presented in figure 3.

The perceived impact of all implemented technological lines and machines in the production process on the individual determinants of bread quality, as assessed by the respondents, is as follows:

- 11.8% – on the establishment of bread yield standards;
- 13.3% – on employee qualifications;
- 13.4% – on recipes;
- 14.6% – on the quality of raw materials used in production;
- 14.8% – on the selection and stability of optimal process parameters;
- 15.8% – on hygienic and sanitary conditions;
- 16.3% – on machine reliability.

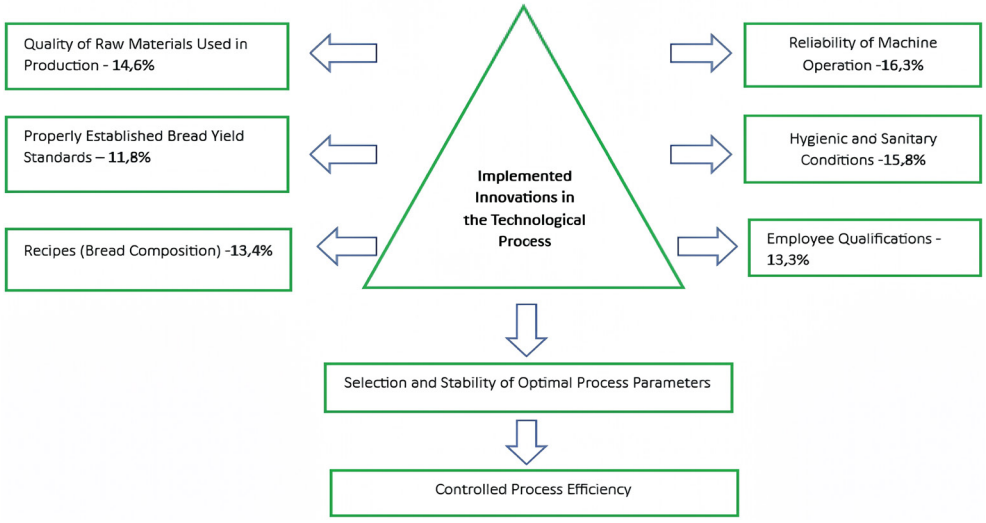

Fig. 3. Model of the impact of innovations in the technological process on the determinants of bread quality (own elaboration)

3.1.4. The comparison of the expected bread quality improvement in the technological process and quality improvements as perceived by the interviewees

When comparing the expected improvement in bread quality within the technological process with the perceptions expressed by respondents, the following conclusions can be drawn. The forecasts regarding the potential influence of innovations on the enhancement of bread quality – based on data from bakery producers collected through questionnaire surveys, domestic and international literature, and participant observations in bakeries – did not substantially differ from the opinions provided by the respondents. In general, it can be concluded that all innovations selected for the study affected the factors that determine bread quality, albeit to varying degrees. The research findings were compared within individual innovation groups.

The first two groups of innovations, namely, technological lines for the production of bread and bakery products, had the greatest impact on the quality-determining factors of bread. For bread production lines, this influence ranged between 3.63 and 4.5 points, while for general bakery production lines, the range was 3.6 to 4.6 points. The magnitude of this impact reflects the extent to which innovations contribute to quality improvement. Automated technological lines influenced the following process-related factors: repeatability and precision of individual production phases; the ability to apply appropriate raw material compositions to ensure the intended nutritional value; perfect synchronization of line operations, ensuring baking occurs precisely at the designated time; the possibility of identifying optimal process parameters; elimination of human error; real-time monitoring and control of technological parameters; protection of raw material quality through adherence to strict technological standards; and the capacity to supply the market with adequate quantities of fresh bread-an aspect of particular importance in the bakery industry.

Frozen dough production lines demonstrated a comparable potential to improve product quality as bakery production lines. Their impact on bread quality determinants was similar, ranging from 3.8 to 4.6 points. These specialized lines, intended for baking rolls and loaves directly at the point of sale, provide consumers with nutritionally valuable products (assuming precise freezing), free from preservatives and colorants, while maintaining the freshness that is highly valued by consumers.

Technological lines involving robots have a varied impact on the factors shaping bread quality, ranging from 2.2 to 4.4 points. Robots operate within specific systems and modify only those tasks that represent a “bottleneck” in the technological process. This explains the diverse influence of installed robots on the individual quality-influencing factors. The benefits of implementing robots primarily related to ensuring hygienic and sanitary conditions as well as enhancing machine reliability, aside from modifying the tasks that the robots are designed to supplement.

The impact of innovative machine systems – mainly automated – on the improvement of bread quality varies depending on the function they serve within the technological process. The silo system ensures proper storage conditions for flour, the primary raw material. The bread quality is significantly improved by the inclusion of sieving and screening systems, airtight containers, strain gauge sensors, and the direct connection to the technological machine line. According to respondents, the impact of silos on the factors influencing bread quality was relatively balanced, ranging from 3.25 to 4.0 points.

Mixers with bowls provide even blending of all dough ingredients within a defined timeframe to achieve an ideal consistency. Their influence on bread quality was also relatively consistent, with scores ranging from 3.33 to 4.0 points. Modern dough proofing chambers ensure all the necessary conditions for this phase of the process, including the appropriate temperature, air humidity, and proofing time for the dough portions. The impact of proofing chambers on bread quality determinants ranged from 3.33 to 4.17 points.

Installed baking ovens – mainly thermal oil and automated systems – maintain the required temperature at a constant level depending on the type of dough being baked. Respondents assessed their impact on bread quality determinants within a range of 3.11 to 4.0 points. X-ray detectors are primarily used to detect foreign objects and reject contaminated bread. Some types of detectors, also installed in the Pomeranian Voivodeship, are capable of identifying product defects such as breakages or deformation, in addition to being able to measure weight. The perceived impact of X-ray detectors on bread quality determinants, as reported by respondents, mainly concerned the quality of raw materials used and hygienic and sanitary conditions. The average score was 2.77 points, indicating a neutral level of acceptance of the issue.

4. DISCUSSION

Innovations implemented in the technological process are mainly directed at introducing changes in product manufacturing methods. Although secondary to product innovations, in the case of bakery products they contribute to improving the quality of this product.

The concept of innovation in producing baked goods as a factor in improving the quality of this product applies to all areas of the bakery business, and creates a holistic picture of the organization's quality-oriented activities. Of all the bakeries included in the survey, 41.5% were micro-enterprises with up to 10 employees, and 27.2% were small enterprises. The dominant problem of modern baking is the process of continuously improving the quality of its baked goods to satisfy customers. Although quality control is essential at every stage of the bakery business, the most important aspect is the technological process.

The literature lacks a comprehensive study how innovations in the technological process improve bread quality. There is also a lack of methodology for conducting such research.

The authors of this article presented and identified factors shaping the quality of bread in the technological process. These factors influencing bread quality in the technological process constitute a functional whole.

In light of this research on how implemented innovations in the technological process impact on the other factors shaping the quality of baked goods, it was found that innovations relate to all factors. However, innovations have the greatest impact on machine reliability. The research also shows that for the respondents, who are mainly associated with the technological department, all factors influencing the quality of bread are equally important. Although the impact of innovations on machine reliability was rated highest and the correctness of setting the bread yield standard was rated lowest, the percentage influence of individual factors influencing bread quality did not differ significantly.

5. CONCLUSIONS

The attempt made in this article to determine how the implemented innovations improve bread quality indicates that the innovations had a significant impact on enhancing bread quality in all groups of automated and robotic machines in the technological process, both for the manufacturer and the consumer. The perfect synchronisation of modern technological lines or specialised automated machines means that the bread baking process takes place at exactly the right time, repeatedly, and meeting strict technological parameters, which has an impact on bread quality.

The baking industry, traditionally known for its craftsmanship, is currently undergoing a noticeable transformation with the introduction of technological lines. While at the beginning of the 21st century, the quality of bread was mainly determined by the knowledge and skills of the baker (Ambroziak, 2002), today it is determined by automated and robotised technological lines or specialised automated machines. It is also a fact that both in the Pomeranian Province and in Poland as a whole, there are still a significant number of micro-enterprises (up to 10 people) where the baker has a major influence on bread quality, e.g. by deciding on the fermentation time, the degree of acidification (multiplication) in individual phases of dough production, the time and intensity of mixing, the time of dough rising, and the temperature and time of baking. As research in the Pomeranian Province has shown, micro-enterprises have also decided to invest in specialised automated machines.

This article presents issues that are very important in a competitive economy. This technical progress in the bread-making process may be a prelude to the Fourth Industrial Revolution, the essence of which is to transfer most decisions from the

competence of humans to that of machines. These research findings indicate that replacing humans with machines is also possible in the baking industry. In addition, machines have an impact on improving the quality of bread, which is also significant in a competitive economy, where consumption patterns are constantly changing.

In the authors' opinion, the attempt to determine the impact of the innovations implemented in the technological process on improving the quality of bread should be continued. The research was conducted during the COVID-19 pandemic, and it was only after its extension to 2023, under the conditions of the National Recovery Plan, that it was possible to identify 56 innovations implemented in bakeries. The implementation of innovations during the COVID-19 pandemic had an impact on both the supply and demand of open innovations, which accounted for 94.7% of the research. As production technology continues to develop, even more innovative applications of automation and robotisation in the technological process can be expected, which will have an impact on the quality of bread.

The authors are convinced of the importance of this, both from a theoretical and empirical perspective.

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INNOWACJE WDROŻONE W PROCESIE TECHNOLOGICZNYM PIECZYWA JAKO CZYNNIK DOSKONALĄCY JAKOŚĆ TEGO PRODUKTU

Streszczenie

Celem artykułu jest określenie wpływu wdrożonych innowacji w procesie technologicznym na doskonalenie jakości pieczywa na przykładzie badań w przedsiębiorstwach branży piekarniczej w województwie pomorskim w latach 2020-2023. Jakość pieczywa jest wynikiem wpływu wielu czynników, które kształtują ją głównie w procesie technologicznym. Jednym z nich są innowacje. W literaturze przedmiotu brak publikacji dotyczących wpływu wdrożonych innowacji w procesie technologicznym na doskonalenie jakości pieczywa.

Zakres artykułu nie wykracza poza proces technologiczny wyodrębniony do celów badań i modelowania. Po *Wprowadzeniu* została przedstawiona *Metodyka badań dotyczących doskonalenia jakości pieczywa w procesie technologicznym na skutek wdrożenia innowacji*. Należy nadmienić, że w warunkach gospodarki konkurencyjnej badania monograficzne są uzależnione od zgody udzielonej przez właścicieli przedsiębiorstw. W tej sytuacji ustalone kierunki badań były przedmiotem współpracy z przedsiębiorstwami branży piekarniczej. Przedsiębiorstwa te nie wyraziły jednak zgody np. na udostępnienie danych *ex ante*.

Badania były prowadzone dwukierunkowo, tj.:

1. Zostało określone oczekiwane doskonalenie jakości pieczywa po wdrożeniu innowacji w procesie technologicznym (zautomatyzowane i zrobotyzowane linie technologiczne oraz specjalistyczne maszyny, głównie zautomatyzowane).
2. Przeprowadzone zostały badania ankietowe dotyczące wpływu wdrożonych innowacji na determinanty jakości pieczywa w procesie technologicznym. W artykule zaprezentowano wyniki tych badań w formie szeregów rozdzielczych strukturalnych wraz z modelem wpływu innowacji w procesie technologicznym na determinanty jakości pieczywa.

Następnie dokonano porównania oczekiwanego doskonalenia jakości pieczywa w procesie technologicznym z postrzeganym przez respondentów (p. 5). Artykuł kończy się *Dyskusją* oraz *Wnioskami*.

Słowa kluczowe: proces technologiczny, doskonalenie jakości pieczywa, czynniki determinujące jakość w procesie technologicznym pieczywa