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Functional model of the impact of factors on product quality in the baking industry

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ABSTRACT:

The article presents factors influencing the quality of the final product in the baking industry. The product in question is mainly bread, comprising 80 to 90 per cent of bakeries' output. The author listed all the factors that impact the product's final quality, ordered them in a systematic fashion and described them. The factors were divided into three groups that function within a manufacturing system, and these were split into sub-groups.
The groups of fundamental factors that influence product quality are related to the materials, technology, techniques and organisation. The summary of this paper contains a functional model of the impact of individual factors on the quality of a bakery product.

Model funkcjonalny wpływu czynników na jakość produktu w branży piekarniczej

Słowa kluczowe: jakość produktu, model funkcjonalny, branża piekarnicza

STRESZCZENIE:

W artykule zostały przedstawione czynniki, które mają wpływ na jakość produktu w branży piekarniczej. Tym produktem jest pieczywo, a w szczególności chleb, który stanowi od 80% do 90% jego ogólnej produkcji. Autor wyodrębnił czynniki wpływające na jakość produktu i usystematyzował je, a następnie opisał. Podzielone one zostały na 3 grupy funkcjonujące w procesie produkcyjnym, a następnie na podgrupy.
Podstawowe grupy czynników, które mają wpływ na jakość produktu to: czynniki surowcowe, czynniki technologiczne i czynniki organizacyjno – techniczne. Podsumowaniem całości opracowania jest opisowy model funkcjonalny wpływu czynników na jakość produktu w branży piekarniczej.

1. INTRODUCTION

Bread is a basic component of every Pole's diet, which, with a rational approach, can play an invaluable role in regulating the human digestive tract and constitute a significant source of the body's daily energy requirements (approx. 25 – 30%) [1]. Bread was, is, and will probably for a long time remain a product of key nutritional importance in Poland.

Many new bakeries were opened following the economic transformation. Simultaneously, a significant increase in bread prices and a change in eating habits, among other factors, have led to a partial reduction in its consumption. Fierce competition has become a problem for the contemporary bakery industry, which has in this article been defined as bakery companies offering bread [2].

Due to its mainly local nature, the bakery industry constitutes an integral part of a region's assets determining its development. The regional market is the main source of raw materials for bakery companies, as well as the main target market for their products. The bakery industry in Poland is one of the most fragmented, as it is mostly composed of medium, small and even micro enterprises [3].

Increased requirements for bread quality from society have engendered a need for new system-based solutions, in which quality becomes a strategic objective. The term quality is difficult to unambiguously define due to its subjective nature [4]. Customer requirements determine the level of product quality, making quality also a multidimensional and interdisciplinary idea [5]. The PN-EN 2842 standard defines quality as a general set of a product's features and properties that shape its ability to meet identified or anticipated needs. The following features determine the quality of bread and other food products:

a) nutritional value – based on the general chemical composition,

b) taste – depending mainly on the composition and quality of the raw materials,

c) health – defined as a lack of risks to consumer health,

d) attractiveness – determined by the shape, colour and packaging,

e) shelf life – ensuring shelf life without quality changes,

f) freshness – equated with the bread's suppleness, aroma and taste [6, 7].

The author, working as a robotisation advisor and subsequently R&D project manager in a bakery, noticed that virtually all operations related to the bread production process impact quality, from the moment raw materials are chosen to when the product reaches a shop. From literature on the subject one can also learn that quality is linked to virtually every aspect of a company's operations and is defined by the tasks performed by its individual parts [8]. Furthermore, the Act on food and nutrition safety stipulates that appropriate quality-centred measures need to be implemented at all stages of food production and trade [9]. Given this situation, the author's focus in this paper was on factors that affect bread quality and compiling them into a descriptive functional model.

2. GROUP OF RAW MATERIAL-RELATED FACTORS

Contemporary factors influencing bread quality stem from changes in the lifestyle of consumers who prefer high-quality products made of high-quality raw materials. The principal raw material factors related to the quality of a bakery industry product are as follows: the quality of the raw materials used in production, correctly established standards for bread production efficiency and the recipe (raw material composition).

Basic raw materials and additives accepted into a production facility warehouse should be of high health and nutritional quality, and demonstrate fitting process suitability. Long-term, proven suppliers are preferred. Furthermore, all raw materials accepted into the bakery's warehouse need to have an appropriate use-by date.

The baking industry has practically no influence on the quality of flour, i.e., the primary raw material. Apart from agricultural and climate conditions, the genetic properties of the cultivated cereal varieties, the correct selection in collection centres, as well as the milling technology, also play a crucial role [7]. The bakery industry does have, however, an influence on the selection of other raw materials of appropriate quality, e.g. yeast, potato flakes, malt or bran, as well as on their storage. The storage conditions determine whether the process suitability and health quality of raw materials improve or worsen.

Flour, mainly wheat flour, is stored in silos. Bakeries have several silos equipped to varying degrees, e.g. with a control system with scales and strain gauges. Such a system gives bakeries full control over the delivery, as well as the use of flour in the process. In addition, a system of screens and sieves installed in the silos, and their hermetic nature guarantee that the raw material is of high quality and clean. The internal silo containers ensure good flour maturation thanks to cyclic aeration.

Another factor affecting the bread quality and, simultaneously, shaping the raw material costs in the bakery industry, are correctly established standards for bread production efficiency, which allow high quality to be maintained. The standard for average bread production yield, i.e. the efficiency, is a quantity that determines the number of kilograms of bread obtained from 100 kg of flour. Every bread producer is obliged to establish a standard average yield for a given type of bread based on a trial bake. Facility standards for average bread production yield include:

a) average flour baking values,
b) average production losses,
c) standard weights of dough pieces,
d) average technical conditions at the bakery.

The above standards should be periodically verified and corrected. For example, in the first half of the year, the biological maturity of grain is better and the flour has a higher baking value – therefore, the standards for bread production yield should be increased for this period. A facility's internal standards of average bread production yield serve as the basis for controlling the consumption of raw materials, also by external inspection bodies.

The right ingredient composition, i.e. the recipe, is the fundamental factor in producing good bread. The recipe should ensure the bread achieves its intended nutritional value and good taste properties when appropriate technology is used. In order to obtain this, basic raw materials and nutritional enhancers, as well as other substances that enrich and improve the finished product, need to be correctly selected.

3. FACTORS RELATED TO THE PROCESS

The group of factors that improves bread quality is primarily process-related. Good bread quality can be ensured through the optimal selection of the manufactured product's process parameters and maintaining the stability of the said parameters.

From the perspective of health-oriented safety, baking is the key stage in the entire bread production process and should, therefore, be performed with great care. This process destroys bacteria, moulds and yeasts from raw materials, fermentation, the environment etc. present in the bread – provided that the appropriate time and temperature were implemented.

Controlled efficiency is essential in every process, especially in the case of food products. This entails regular checks and analyses of all process stages, as well as inter-operational quality control of intermediate products. Control and assessment of temperature, stage efficiency, souring degree and fermentation time have a decisive influence over process efficiency, as well as the quality of the produced bread.

The temperature depends on baking efficiency and duration. At lower temperatures, souring is slower to occur and a significant amount of acetic acid is produced. The quantitative ratio of acetic and lactic acid to a large extent dictates the smell and taste of the bread. Large bakeries, following the example of some European Union countries, adopt an additional criterion for correct baking – the temperature inside the product when it leaves the oven.

The stage efficiency, i.e. the quantitative ratio of water to flour, affects microflora development and activity. It determines the moisture and texture of the intermediate product. It can be assumed that the more water is added, the greater the efficiency and the looser the texture. However, the looser texture stimulates enzyme reactions, leading to a greater amount of soluble substances that feed microorganisms. However, if too little water is used in preparing the dough, starch pasting will be poor during baking.

The acidification level is the ratio of the flour weight in the prepared stage to the fermented flour weight introduced in the preceding phase.

The levels used in baking depend on the fermentation time for the stage, the quality of the raw material and the production process scheme. For yeasts, a greater degree of acidification is beneficial, while the opposite is true for bacteria.
The fermentation time depends on the stage yield, temperature and acidification level. It is associated with a change in acidity. The starting point for developing a fermentation scheme is the assumed fermentation time. The other parameters are adjusted appropriately.
In summary, it can be said that bakery companies can, even must, regulate the temperature, the degree of acidification and fermentation time for the phases, as these treatments improve the product quality.
The manner in which the process of obtaining a final product of appropriate quality is managed, is also based on the inter-operational control of intermediate product quality. Such control is necessary because, once process irregularities are discovered, it is possible to prevent poor-quality bread by changing the conditions, for example of fermentation (changing the process duration, temperature, stage yield). Therefore, testing of intermediate products is needed both for trial baking, as well as for continuous bread production. Inter-operational control of intermediate product quality is performed mainly by in-house laboratories, usually located in the vicinity of production halls. Most often these laboratories use the organoleptic and physico-chemical methods to evaluate intermediate bakery products. Researchers working on new and more accurate quality evaluation methods prefer microbiological methods, but these are expensive and more time-consuming [10].
The organoleptic method includes such qualitative characteristics as: external appearance, aroma, structure and maturity of the fermentation phases. Depending on its maturity, each of the intermediate products has an appropriate aroma. For example, mature leaven /pre-ferment/ has an alcohol-yeast fragrance, aromatic and pleasant. Meanwhile, the structure of intermediate /fermentation/ products is assessed after gently removing the top layer of the tested intermediate product. For example, mature pre-ferment has a spongy structure with almost uniform pores, while in the initial stage it should have a loose consistency and a more porous structure, with thin-walled pores. The dough's maturity is checked by pressing lightly with fingers on the surface. If the dough immediately returns to its previous position once the pressure is released, it is not yet mature. If the surface sags slightly where pressure is applied, the dough is already mature.
The physical-chemical method of checking intermediate products includes: temperature, humidity, acidity and consistency. It is recommended to check the temperature with an electronic gauge equipped with a sensor adapted for baking. The moisture of intermediate products is determined by drying them in a dryer (tray or cabinet), while the water content is calculated on the basis of the sample's weight difference, before and after drying. The potential acidity of intermediate products is expressed in degrees and determined by titrating an aqueous suspension of a dough sample with a sodium hydroxide solution, and checking with a phenolphthalein indicator. The active acidity /ph/ is determined using a pH meter and its result read off its scale. Acidity control is especially important for rye bread intermediates, as it enables proper fermentation. The consistency of the dough is determined using a consistograph or a farinograph. Large deviations in the consistency doughs may cause: disruptions in the production schedule, difficulties in dough processing, inadequate bread quality and loss of raw materials.

4. ORGANISATIONAL AND TECHNICAL FACTORS

Bread quality is a complex system and comprises a set of features, of which the customers most appreciates freshness. Commercial bakery products are delivered every day, so bread production machines should be kept in fully operational condition at all times. No studies regarding machine reliability in the bakery industry have appeared so far in Polish and foreign scientific literature. The author has, based on literature and his own research, undertaken to analyse the reliability of machines in the bread production process through adopting a probabilistic approach [11]. The following distributions were helpful in this work: exponential, Weibull, Gamma, normal and log-normal [12, 13]. Research on the reliability of baking industry machinery, from a probabilistic perspective, has not been performed in Poland so far. Given the fact robots were being introduced to the production line in the studied bakery in-

dustry company, the author had the opportunity to analyse machine reliability in the 2016-2019 period, both in a traditional bread production system and after robotisation. The results of the above empirical analysis were measurable: in a traditional configuration of machine assemblies the reliability was 78.54%, while after robotisation it was 89.21%.

Based on the presented results, it can be concluded that robotisation, which is the next stage of automation, had a significant impact on machine reliability [14, 15]. Robots replace human labour and improve hygiene standards, which reduces the risk of poisoning among customers. Furthermore, robots do not experience tiredness or frustration when performing monotonous activities at the production line, they do not get sick and do not pose a disease risk in the production process. Their scope for error is also limited, for example in the raw material mixing process. In bakeries, robots reduce the level of flour dust in rooms, which creates conditions for the development of microorganisms and mould when combined with humidity and high air temperatures. Robotisation in bakeries also entails repeatability, accuracy, as well as significantly increased process efficiency, which all greatly affect the quality of bread delivered to the market [16, 17].

In the bakery covered by the study, an x-ray detector was installed along with two robots. It detects contaminants in bread, such as metal, stones, glass or plastic and, therefore, allowed defective bread to be completely eliminated.

Increasing automation is the main goal of Industry 4.0, which is based on the integration of new technical solutions. The integration of intelligent, networked and autonomous digital and physical technologies, of which robotics is a part, brings with it new opportunities for innovation and development of production lines. The fourth industrial revolution is a development opportunity, especially for small and medium-sized manufacturing enterprises, which forms a group most bakeries belong to. It is also a fact that the barrier to access the latest production technologies is increasingly easier to overcome, and companies react in a faster and more flexible way to market needs [18-21].

The quality of bread is greatly affected by the hygienic and sanitary conditions in bakeries, mainly within the scope of ensuring health safety. The hygienic and sanitary conditions apply in particular to machines, bread storage, packaging and transport.

The hygiene requirements for machines are included in the standard: PN - EN 1672 - 2:1999 “Food processing machinery. Basic concepts. Hygiene requirements”. According to them, the surfaces of machines and devices should be easy to clean and disinfect. Additionally, the locations for machines need to be chosen so as to allow convenient cleaning and cleanliness in the machine’s surroundings to be maintained.

Bread quality is also affected by the storage conditions after baking. First of all, the bread should be chilled in conditions preventing secondary contamination (with raw materials, equipment, people, the environment, etc. as factors) – in clean rooms with limited personnel movement. Bread cannot be placed in corridors, on ramps, etc. The trolleys used for bread need to be clean; with the lowest shelf at least 30 cm above the floor.

Bread packaging includes slicing and packaging. Individual bread packaging is used for hygienic reasons and to extend shelf life. Packaged bread is subjected to thermal stabilisation or a modified atmosphere is employed. Some bread is delivered to the market without packaging, therefore maintaining hygienic conditions and personal hygiene among employees is of particular importance.

Bread should be transported to shops by personnel not posing a risk to health. Means of transport should be clean, free of other aromas and used only for this purpose. They should also be washed every day and disinfected periodically.

A comprehensive check of the quality of all bread types after baking is conducted through scoring. It includes an organoleptic assessment with consideration for physical and chemical indicators. The points obtained in the assessment serve as the basis for classifying bread quality. Bread that fails to receive the minimum number of points is disqualified.

However, testing the final product alone is not sufficient to determine its quality. Only employing an appropriate system of planned quality-oriented activities over the entire production chain, starting with raw materials and ending with the distribution of bread to shops, guarantees that the goal can be achieved, i.e. good-quality bread produced, with the safety of the bread for consumption guaranteed.

5. FUNCTIONAL MODEL OF THE IMPACT OF FACTORS ON PRODUCT QUALITY IN THE BAKERY INDUSTRY

The division of factors performed and their description, as well as the functional relationships between them in the production process, served as the basis for the development of a descriptive model of the functional impact of the factors on the product quality in the bakery industry, as shown in Figure 1.

The model features visible direct and indirect dependencies. The quality of the raw materials used and the ingredient composition, i.e. the recipe, are examples of a direct impact on product quality. These factors directly influence the bread quality, but they enter the process through the managing body, which is responsible for selecting optimal process parameters, as well as ensuring their stability. Each process requires control over process efficiency. This entails regular checks and analysis of:

a) efficiency standards set for individual types of bread,

b) production process stages,

c)quality of intermediate products.

6. CONCLUSIONS

Virtually all operations in the bread production process, from the selection of raw materials to its arrival at a shop, influence the bread quality. For this reason, the author has identified factors affecting bread quality, organised and discussed them in this document. These factors have been divided into 3 groups comprising the production process, and further into subgroups, as shown in this list:

I. Group of raw material factors, including:

1. Quality of the raw materials used for production.

2. Correctly established bread efficiency standards.

3. Recipes /raw material composition/.

II. Factors related to the process, i.e.:

1. Selection and stability of optimal process parameters.

2. Controlled process efficiency, including:

a) control of individual production process stages,

b) inter-operational control of the quality of intermediate products.

III. Organisational and technical factors, including:

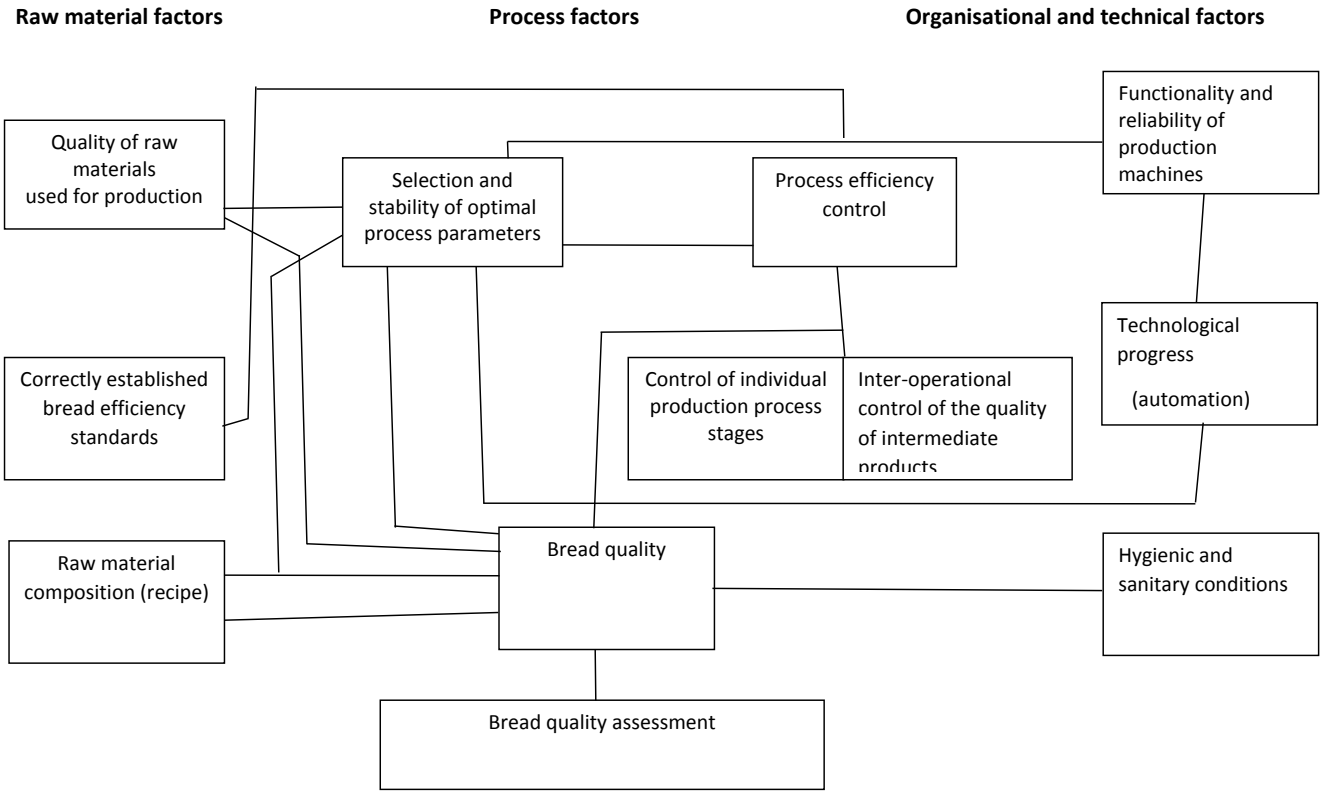

Figure 1 Functional model of the influence of factors on product quality in the bakery industry# (source: own study)

1. Functionality and reliability of production machines.
2. Technological progress.
3. Hygienic and sanitary conditions.

The method, scope and influence on the proper use of the indicated quality factors depends on each producer in the bakery industry. The descriptive functional model of the impact factors have on product quality in the bakery industry prepared here, consists in a summary of all the discussed factors, as well as their direct and indirect connections in the production process.

In this study, the author endeavoured to demonstrate that in the bakery industry the only guarantee of good quality bread is to implement appropriate quality-oriented actions over the entire production chain, from the selection of raw materials to the distribution of bread to shops.

As the author's probabilistic tests show, the reliability of machines is closely related to technical progress. The study mentioned robotisation, whose appearance in bakeries had tangible results. In the traditional configuration of a machine set, the reliability was 78.54%, while after robotisation it rose to 89.21%. Such studies have not been performed in Poland so far.

The presented research results have great practical implications within the scope of the constantly growing interest in robotisation. They can be implemented by potential recipients from the baking industry as examples of increasing the operational availability and efficiency of production machines, as well as increasing product quality.

BIBLIOGRAPHY

[1] Gambuś H., Litwinek D., „Pieczywo – dlaczego warto jeść i jakie wybierać", Uniwersytet Rolniczy w Krakowie – Wydział Technologii Żywności, Kraków 2011.

[2] Gorynia M., Jankowska E., Maślak E., Branża jako przedmiot badań w ekonomii, „Gospodarka Narodowa" No 3/2003.

[3] Kamińska A., Regionalne determinanty rozwoju małych i średnich przedsiębiorstw, Difin, Warszawa 2011.

[4] Lisiecka K., „Dylematy etyczne w biznesie zrównoważonego rozwoju na przykładzie certyfikacji systemów zarządzania jakością", Problemy Jakości, No 12 /2010.

[5] Tejże, „Systemy zarządzania jakością i kryteria pomiaru ich efektywności", Problemy Jakości, No 9/2001.

[6] Balon U., Dziadkowiec J. M., Sikora T., Cechy jakości żywności a decyzje zakupowe polskich konsumentów soków owocowych, Uniwersytet Ekonomiczny w Krakowie, Katedra Zarządzania Jakością, Kraków 2016.

[7] Zakład Badawczy Przemysłu Piekarskiego, Piekarstwo – receptury, normy, porady i przepisy prawne, Handlowo – Usługowa Spółdzielnia „Samopomoc Chłopska", Warszawa 2002.

[8] Grudowski P., „Podstawy ustalania zakresu systemu zarządzania jakością", Q jakości, No 3, 2004.

[9] Act of 11 May 2001 on health conditions for food and nutrition /Journal of Laws of 2001, no. 63, item 634, as amended/.

[10] Madej-Lachowska M., Szwedziak K., Polańczyk E., Piechaczek N., „Ocena jakości wybranych produktów żywnościowych za pomocą metod wizyjnych", Postępy Techniki Przetwórstwa Spożywczego, No 1 /2015.

[11] Drozd R., „Niezawodność maszyn produkcyjnych w branży piekarniczej – zagadnienia teoretyczne i praktyczne", Aparatura Badawcza i Dydaktyczna, No 3/2019.

[12] Bobrowski D., Modele i metody matematyczne teorii niezawodności w przykładach i zadaniach, Wydawnictwa Naukowo-Techniczne, Warszawa 2000.
[13] Migdalski J., (ed.) Inżynieria niezawodności. Wydawnictwo ATR, Bydgoszcz i ZETOM Warszawa 2000.
[14] Drozd R., „Wpływ robotyzacji na niezawodność procesu produkcyjnego w branży piekarniczej," Aparatura Badawcza i Dydaktyczna, No 3/2019.
[15] Hawryluk P., „Automatyzacja i robotyzacja procesów produkcji – trudność czy konieczność", Transport Przemysłowy i Maszyny Rolnicze, Vol. 1/2019 pp 74 and 75, HMR – TRANS Sp. z o.o., Wrocław 2019.
[16] Barczyk J., „Robotyzacja w przemyśle spożywczym", Pomiary Automatyka Robotyka, no. 1/2007.
[17] Kaczmarek W., Panasiuk J., „Roboty w typowych procesach i aplikacjach", Automatyka, Book 6/2015.
[18] Zdanowicz R., Podstawy robotyki, Wydawnictwo Politechniki Śląskiej, Gliwice 2012.
[19] Gilchrist A., Industry 4.0 The industrial internet of things, Wydawnictwo Apress USA, 2016.
[20] Lass S., Gronau N., A factory operating system for extending existing factories to Industry 4.0. Comput. Ind., 115, 2020.
[21] Miśkiewicz R., Wolniak R., Practical Application of the Industry 4.0 Concept in a Steel Company, Sustainability, 10.3390/su12145776, 12, 14, (5776), 2020.