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FACTORS INFLUENCING QUALITY AND SHELF LIFE OF BAKING PRODUCTS

UTICAJNI FAKTORI NA KVALITET I ROK UPOTREBE PEKARSKIH PROIZVODA

Izabella KWAŚNIEWSKA-KAROLAK, Justyna ROSICKA-KACZMAREK, Lucjan KRALA
Institute of Chemical Technology of Food, Technical University of Lodz,
ul. Stefanowskiego 4/10 90-924 Lodz, Poland
e-mail: izabella.kwasniewska-karolak@p.lodz.pl

ABSTRACT

Bread is one of the oldest foods. Recipes and technology of baking have been modified to elongate its shelf-life and adapt to changing consumers' preferences. Currently, highly acceptable sensory attributes of bread have been achieved using numerous preparations such enzymes, components improving its volume and antifungal compounds. Bakery products have a short shelf-life, resulting from adverse changes that begin just after baking and cause worsening of sensory features and texture of crumb. Elongation of the shelf-life has been achieved not only through recipe improvement but also packaging under modified atmosphere (MAP), application of intelligent packages or interrupted bread-making. All these approaches are designed to produce the highest quality bread retaining quality till the end of shelf-life. Maintenance of bread freshness has attracted attention of bread manufacturers and consumers for years. This paper is a review of recent literature related to methods of bread shelf-life elongation.

***Key words**: bread, shelf-life, storage, additives.*

REZIME

Hleb je jedna od najstarijih namirnica. Recepti i tehnologija pečenja su modifikovani da produže rok trajanja i prilagode promenljivim zahtevima potrošača. Trenutno, visoko prihvatljive senzorne osobine hleba postignute su koristeći brojne preparate što su enzimi, komponente za poboljšanje zapremine i antifungalna jedinjenja. Pekarski proizvodi imaju kratak rok trajanja, kao posledica nepovoljnih promena koje počinju već nakon pečenja i izazvaju pogoršanje senzornih karakteristika i mrvičastu teksturu. Produženje roka trajanja je postignut one samo kroz poboljšanje recepata nego i pakovanjem u modifikovanoj atmosferi (MAP), primenom inteligentnih. Svi pristupi su dizajnirani da proizvodu hleb najvišeg kvaliteta sa mogućnošću očuvanja kvaliteta do kraja roka upotrebe. Održavanje svežine hleba godinama privlači pažnju proizvođača kao i potrošača. Ovaj rad je pregled novije literature koji se odnosi na metode produženja roka upotrebe hleba.

***Ključne reči:** hleb, rok trajanja, skladištenje, aditivi.*

INTRODUCTION

Bread-making technology has been changing for years. Traditional recipes were based on appropriate proportions of flour, leavening agent, water and salt. Currently bread has been manufactured using additional substances such as fats, milk, improved leavening agents, cereal grains, enzymes. These additives along with optimized parameters of technological process were found to improve its sensory and nutritive characteristics (*Fik, 2004*). Cereal products including bread are recommended diet element representing the base of Food Guide Pyramid. Bread is rich in diverse nutrients such as: carbohydrates, proteins, fats, mineral substances, B-complex vitamins, vitamin E and other valuable diet components.

Bread quality is of importance because it is commonly consumed (*Ambroziak, 1998*). However, it is difficult to define this quality since it is affected by many factors such as the nutritive value, taste, freshness, shelf-life and attractiveness for consumers. Bakery products have a short shelf-life, resulting from adverse changes that begin just after baking and cause worsening of sensory features and texture of crumb. Ageing of bread is manifested by a partial decrease in humidity, growth of filamentous fungi and yeasts, and staling *(Fik 2004)*. Bread staling has been investigated by numerous researchers both in Poland and abroad (*Fik et al., 2000; Scanlon et al., 2000; Michalska-Pożoga and Raczkowska, 2011*). Many of these studies focused on shelf-life extending through improvements in manufacturing technology or application of additives.

MATERIAL AND METHOD

Bakery products account for around 70% of all consumed cereal products. Their chemical composition, and nutritive and energy values depend on formulation, conditions of dough preparing and further steps of technological process, and additives (*Grembecka, 2007*). Bakery products are classified based on not only the type of flour, but also on conditions of bread-making or applied additives. Rye breads are produced from either leavened rye flour or using a pre-fermented leaven. Mixed rye breads are manufactured from mixtures of rye and wheat flours that are either subjected to leavening or mixed with the leaven, which can be supplemented with yeasts. Wheat bakery products are derived from wheat flour fermented with yeasts.

Bakery products are also classified based on the ash content in the flour. Dark bakery products are produced from flours containing more than 1.0% ash or from mixtures of flours with ash content above 1.06%. White bakery products are manufactured from flours with ash content below 1.0% or their mixtures (*Ambroziak, 1998*). Types of bread depend also on a country and tradition, which in turn depend on available cereals and sorts of flour.

Special, regional types of bakery products that are available on the market are either characterized by specific formulations or produced by unique technological processes (e.g. wheat bread rich in dietary fiber and vitamins, bread enriched with cereal bran, crisp bread, pumpernickel and durable bread, also named conserved bread). Also dietetic breads differ from commonly manufactured bakery.

Examples of dietetic bakery products are: high-protein bread, gluten-rich bread, gluten-free bread, low-sodium bread and rusks enriched with iron salts (*Ceglińska, 2006*).

Chemical composition of bread

Bakery products are rich in carbohydrates because of the high content of starch and simple saccharides. Levels of the latter carbohydrates depend not only on chemical composition of flour but also on amounts of sugars added during manufacturing process. Therefore, wheat bakery products usually contain more sugars than rye bread, which is not supplemented with other carbohydrates. Bakery products are an important source of dietary fiber apart from fruits and vegetables. Its content depends on a sort of flour and varies between 0.3 and 1.5 g/100 g fresh bread. Therefore, wholemeal breads contain elevated levels of dietary fiber. The latter is not digested in human gastrointestinal tract but positively affects peristalsis of intestines and enables expelling of harmful metabolites. Cellulose and hemicelluloses are main fractions of dietary fiber in wheat bakery products while in rye breads it embraces: pectin, gums and mucus substances (*Ambroziak, 1998; Wojciechowicz and Gil, 2009*).

Flour type and dietary fiber content influence also about concentration of other nutrients. Wholemeal wheat and rye breads contain 2-5-fold more salts of iron, magnesium, manganese, copper and zinc than white breads (*Ambroziak, 1998*).

Protein content in varies between 4.5 and 8.0 g/100 g fresh bread. Although wheat bakery products contain more proteins than rye breads, rye proteins are more valuable because of higher amounts of essential amino acid. Fat content in bakery products is low and varies between 0.7% and 2.5%. Therefore, bread can be kept for a relatively long time. Bakery products are rich in B-complex vitamins, in particular thiamine (vitamin B_1), niacin, riboflavin, and folic acid as well as vitamin E. Higher levels of these valuable ingredients are contained in wholemeal breads, particularly yeast-fermented wheat breads. Humidity content in rye breads reaches 50%, while in wheat breads it is up to 45% (*Ambroziak, 1998*).

Energy value of bakery products varies between 874 and 1924 kJ, it means 208-459 kcal/100 g fresh product with exception of pumpernickel and crisp breads, which are characterized by the higher energy value and content of nutrients (*Ambroziak, 1998*).

It is estimated that bakery products satisfy around 50% of nutritional needs of human and around 30% of energy needs.

RESULTS AND DISCUSSION

Preservation of foods including bread and other bakery products is based on methods that aim at extending their shelf-life through inhibition of microbial growth, retarding adverse chemical, biological or physical changes or protection from diverse contaminations and pests.

There are several methods extending the shelf-life of bakery products such as:

1. Freezing; 2. Packaging; 3. Thermal processing; 4. Bioconservation; 5. Chemical agents; 6. Other.

Freezing

Freezing is one of most widely used methods of bread preservation although it only slows down adverse physicochemical changes and does not eliminate them completely (*Postolski, 2002; Barcenas and Rosell, 2006; Skotnicka and Palich, 2007*). Freezing reduces losses of nutrients and worsening of sensory attributes during prolonged storage (*Berliński and Bońca, 2007*). This method is used mainly to prevent staling of bakery products through inhibition of starch retrogradation process (*Ambroziak, 1999; Skotnicka and Palich, 2007*). One of most important technological parameters, influencing the ultimate quality of frozen products and their further shelf-life, is freezing rate. According to recommendations of the International Institute of Refrigeration, the temperature of bakery products should be quickly decreased to -7 °C (*Polak et al., 2004; Yi and Kerr, 2009*). Freezing is conducted by two methods: blast freezing with cold air and cryogenic.

Packaging

Objectives of packaging of bakery products include prevention of microbial contamination and maintenance of acceptable sensory properties. Besides, packaging should prevent a decrease in humidity. Bakery products with a relatively short shelf-life (1-2 days) are packaged in paper bags or perforated foils. Foil bags from PE-LD and PE-LLD are used to package sliced breads or specialty breads with a shelf-life of a few days as well as frozen bakery products. Products with an extended shelf-life should be packaged in polypropylene (PP) heat shrink and extensible foils. Because these foils are barriers to steam and other gases contained in air and are resistant at elevated temperature, they can be used to package hot and thermally preserved bakery products. Delicacies, semi-confectionery products may be packaged in two-layer foils like polyamide/polyethylene foils or foils consisting of two types of polyethylene e.g. PE-HD/PE-LD (*Michniewicz, 1998*).

The shelf-life of bread and other bakery products may be also extended through packaging in modified atmosphere (MAP). This technology is based on replacement of air with inert gases. Bakery products are usually packaged in the atmosphere containing various proportions of carbon dioxide and nitrogen. Composition of recommended gas mixtures and resulting increase in bakery products' shelf-life is shown in Table 1 (*Guynot, 2003; Yi and Kerr, 2009; Fik et al., 2012*).

Active packages used in food industry contain substances absorbing oxygen, which are usually entrapped inside small bags that are put inside the package. Depletion of oxygen prevents the growth of filamentous fungi thereby extending the shelf-life of foods like bread and other bakery products. One of these oxygen absorbers is a preparation named "Ageless", which causes a 3-fold increase in a shelf-life of rolls kept in the atmosphere of inert gases (*Tab. 2*) (*Yi and Kerr, 2009*).

Table 1. Composition of gas mixtures used in MAP of selected bakery products and their shelf-life (Yi and Kerr, 2009)

A sort of bakery products	Gas mixture composition		Temperature of storage [°C]	Shelf-life [days]
	CO_2 [%]	N_2 [%]		
Sliced rye bread	70	30	5	21-28
Sliced toast bread	80	20	20	14-21
Baked rolls	70	30	5	21-28
Pizza	50	50	5	14-21

Table 2. Shelf-life of bread kept in active packages at temperature of 25 °C (Yi and Kerr, 2009)

Atmosphere composition	Time until appearance of filamentous fungi [days]
Atmospheric air	5-6
CO_2/N_2 (60:40)	16-18
N_2	9-11
Atmospheric air + "Ageless"	>60
CO_2/N_2 (60:40) + "Ageless"	>60
N_2 + "Ageless"	>60

An alternative to bread packaging in the modified atmosphere (MAP), which insufficiently protects it from the growth of fungi (*Nielsen and Rios, 2000*) is application of active packages filled with volatile essential oils (EO) or oleoresins (OL) derived from spices and herbs. The antibacterial and fungistatic activities of these substances were proven by numerous studies (*Azzouz and Bullerman, 1982; Shelef, 1983; Conner and Beuchat, 1984; Zaika, 1988*). Essential oils are used in such concentrations which affect neither the taste nor the aroma of protected products.

According to Nielsen and Rios (*2000*), the highest fungistatic activity was displayed by white mustard oil. Cinnamon, garlic and clone oils were only slightly less active. The shelf-life of rye bread was elongated when it was kept in an active package containing the white mustard oil containing - allyl isothiocyanate, which inhibits the growth of fungi.

Thermal preservation

Thermal preservation considerably extends the shelf-life of bread and other bakery products. They are packaged in polypropylene foil and subjected to pasteurization. To destroy fungal spores the temperature of the core of bread crumb is increased to 85 °C and maintained at this level for 15 min. Temperature and duration of bread processing depend on its type, package and available equipment. Thermal processing may be conducted using a baking oven equipped with a system ensuring the maintenance of constant temperature or inside a switched-off baking oven, whose temperature is gradually decreasing (*Michniewicz et al., 1992*).

Bioconservation

Bioconservation is an alternative method of bread preservation based on biological activity of lactic acid bacteria (LAB) that dominate the microflora of leaven. one of the attributes of this bacterium is the capability of inhibiting the growth of other microorganisms, which are responsible for the microbial spoilage of bread. Many species of lactic acid bacteria populating the leaven are members of genus *Lactobacillus* (*Dal Bello et al., 2007; Ryan et al., 2008*). Antagonistic activity of LAB strains is caused by synthesis of compounds strongly suppressing the growth of other microorganisms like organic acids, hydrogen peroxide and bacteriocins. Depletion of oxygen in the leaven is another factor terminating the growth of filamentous fungi and other aerobic microorganisms. Organic acids produced by LAB strains, which are protonated at low pH, cross the cytoplasm membrane of microbial cells and release protons at neutral pH inside these cells. The increased H^+ uptake leads to acidifying the cells and disturbance of proton gradient across the cytoplasm membrane thereby decreasing the protonmotive force, which is essential for ATP synthesis and metabolic activity of cells. Besides, the accumulated toxic anions interact with cell constituents, which is also harmful to microorganisms. Lactic acid shows the higher activity in inhibition of microbial growth that acetic acid with an exception of yeasts and filamentous fungi.

Hydrogen peroxide produced by LAB strains activates the lactoperoxidase system. Its products show antibacterial activity, in particular toward gram-negative bacteria of genera *Escherichia*, *Salmonella* and *Pseudomonas*. Bacteriocins, which are ribosomally synthesized peptides or proteins of LAB strains giving their producers a competitive advantage in the environment, cross cell walls of other bacteria and form ionic channels in the cytoplasm membrane, which triggers its depolarization leading to ceasing of protonomotive force and cell's death (*Włodarczyk and Diowksz, 1998; Diowksz, 2004; Kowalski, 2005; Piesiewicz, 2005*).

Chemical agents

As it was mentioned above, bakery products have a short shelf-life due to adverse changes that begin just after baking and cause worsening of sensory attributes and texture of crumb. Staling is the most important process causing a loss of bread quality. It is defined as an alteration of properties of bread and other bakery products, which is not caused by microorganisms (*Michniewicz 1998, Ambroziak 1999, Gil et al., 1999; Marzec et al., 2007*). Staling is manifested by crumb hardening, changes in the color of crust, a decrease in solubility of starch and its recrystallization, and reduced water binding capacity of crumb (*Hoseney and Miller, 1998; Van Dam and Hille, 1992*). These processes occur at various rates and contribute to increasing hardness, dryness and fragility of crumb, decreased crispness of crust and a loss of aroma, causing ageing of bread and gradual loss of usefulness as a food (*Bhattacharya et al., 2002; Fik, 2004; Le Bail and Ribotta, 2007*).

The improvement of the quality of bakery products and elongation of their shelf-life may be achieved using preparations of enzymes like amylases, lipases, proteases (*Tenkanen et al., 1998*), cellulases (*Haros et al., 2002*) or pentosanases. Other additives retarding the process of ageing are volume increasing agents, antifungal substances and other (lipids, preparations of malt, milk and dairy products etc.) (*Jakubczyk, 1988; Ambroziak, 1998; Drozdowski, 2007).*

In recent years it has been observed an increasing interest in grains of cereals, which have not been used to bake bread, as additives to bakery products. Examples of such cereals are: oats, barley, buckwheat, sunflower, amarantus and quinoa. Their application as bread additives results from valuable chemical composition since they are rich in dietary fiber, unsaturated fatty acids, mineral salts, B-complex vitamins and antioxidants. Additionally, they have either low or medium glycemic index (*Diowksz, 2010a ; Diowksz 2010b*)

Enzymatic preparations

Increasing availability of microbial enzymatic preparations gave rise to their numerous applications in food processing including baking. Enzymatic preparations are added to dough to modify its components. For instance, amylases catalyze depolymerization of starch to dextrins and short oligosaccharides, which improves the porosity of crumb and increases its volume (*Akers and Hoseney, 1994; Morgan et al., 1997; Yaseen et al., 2001; Caballero et al., 2007*). Most suitable for this purpose are thermostable enzymes, which retain their activity at temperatures higher than the temperature of starch gelatinization and are thermally inactivated in late phases of baking (*Fik, 2004*). Commonly used in industry extracellular enzymes from *Aspergillus niger* and *Bacillus megaterium* display medium thermostability (*Hebeda et al., 1991; Burrington, 1998*). An example of amylolytic enzymes efficiently retarding bread staling are α-amylases (*Laurikainen et al., 1998*). Low molecular weight dextrins released from starch by these enzymes retard retrogradation of amylopectin and formation of cross-links between gluten and granules of gelatinized starch (*Martin and Hoseney, 1991; Akers and Hoseney, 1994*). α-Amylases act in a random manner and produce also some glucose stimulating the growth of yeasts and fermentation, which in turn give rise to formation of larger amounts of carbon dioxide and positively affect the texture of bakery products (*Fik, 2004*). The occurrence of starch depolymerization products contributes to the higher intensity of Maillard reactions during baking and thereby improves bread taste and coloration of the crust.

Treatment of dough with α-amylases reduces to some extent bread staling. However, it was found that when the extent of starch depolymerization catalyzed by thermostable α-amylase from *Bacillus subtilis* strain was too high (the applied enzyme dose was too large) the quality of crumb was worsened due to the overproduction of soluble dextrins, which caused bread collapse immediately after taking out from oven. Besides, the crumb became rubber-like and viscous, which considerably hindered slicing (*Qi Si and Drost-Lustenberge, 2002*). Too high activity of fungal α-amylases used for dough treatment caused that the crust was too dark while the crumb was stretching. A good alternative seems to be dough treatment with malt α-amylase, which is thermally inactivated at the end of baking. This enzyme converts gelatinized starch to long dextrins and does not cause its more advanced depolymerization. It also does not affect rheological properties of dough because its activity at temperature below 35 °C is low. This in turn minimizes the risk of disadvantageous changes of the dough, which are observed when the amylolytic activity is too high. Application of the latter α-amylase increased the shelf-life of bread by 4 days (*Qi Si and Drost-Lustenberger, 2002; Goesaert et al., 2009*).

Also other enzymes such as lipases, proteases, cellulases and pentosanases were successfully used for dough treatment resulting in extended shelf-life of bakery products (*Olesen et al., 1994; Rouau et al., 1994; Tenkanen et al., 1998; Laurikainen et al., 1998; Haros et al., 2002; Katina et al., 2006; Caballero et al., 2007*). Proteases are applied to loosen the structure of gluten, which in turn improves crumb structure (*Fik, 2004*).

Lipases catalyze hydrolysis of tri-, di- and monoacylglycerols contained in fats added to dough, which gives rise to the increase in softness of the crumb (*Krog et al., 1989*). This treatment improves loaf volume and structure of crumb, which becomes delicate, uniform and whiter. Products of fat hydrolysis released by lipases have emulsifying properties and therefore they can replace a part of emulsifiers, which are added to the dough (*Spendler et al., 2001; Christiansen et al., 2003; Moayedallaie et al., 2010*). This in turn may reduce costs of transportation and storage of emulsifiers, which are kept either in refrigerating conditions or frozen. The improvement in dough properties is caused by an increase in gluten strength, however, a too high enzyme dose gives rise to negative effects because the crumb becomes stiff and the volume yield is too low. (*Krog et al., 1989, Qi Si and Drost-Lustenberger, 2002*).

Other enzymes that are used for dough treatment are xylanases and pentosanases, enhancing the stability of dough, improving the structure of crumb, which becomes more delicate, and increasing loaf volume (*Laurikainen et al., 1998; Qi Si and Drost-Lustenberger, 2002*). Pentosanases catalyze the hydrolysis of pentosans, which gives rise to more uniform distribution of water in loaves and prevent the phenomenon of separation of crumb and crust during baking (*Rouau et al., 1994*). The action of xylanases increases the strength and elasticity of gluten. However, the complete disappearance of pentosans from the dough is disadvantageous because they are necessary for water binding. When the degree of pentosans hydrolysis is too high the crumb becomes viscous. The treatment of dough with both xylanases and fungal α–amylases gives the synergistic effect (*Qi Si and Drost-Lustenberger, 2002*).

Other additives

Shelf-life of bakery products may be also extended by supplementing either flour or dough with natural or synthetic additives like emulsifiers and hydrocolloids (*Hebeda et al., 1991; Korus and Achremowicz, 1994*). They interact with cereal proteins during dough mixing thereby strengthening their structure, increasing elasticity of crumb and extending bread freshness, because they bind to starch during baking. Commonly used emulsifiers are mono- and diacylglycerols and other esters of fatty acids. One of natural emulsifiers is lecithin (*Ambroziak, 1998*). It was found that the crumb of bread supplemented with rapeseed or soybean lecithin was softer and more porous. Concomitantly, the loaf volume was increased and bread staling was slower (*Haber et al., 1992; Lewczuk and Sobczyk, 1994*). Addition of hydrocolloids was found to positively affect physical properties of gluten and retard hardening of crumb *(Davidou et al., 1996*).

Both the shelf-life and quality of bakery products were improved by addition of endogenous flour lipids (*Kweon and Park, 1994; Collar et al., 1998*), which decreased the rate of staling and hardening of crumb through formation of complexes with starch during baking (*Soral-Śmietana, 1989*).

Also the enrichment of dough with proteins, wheat gluten, soybean flour or rich in proteins dairy products had a positive impact (*Gallagher et al., 2002*). Addition of defatted milk or whey improved the porosity and elasticity of bread crumb, crust coloration, nutritive value and taste of bread (*Erdogdu-Arnoczky et al., 1996, Mannie and Asp, 1999*).

Bread quality was also improved through addition of non-starchy polymers, like pentosans (arabinoxylans), cellulose, lignin, betaglucans and pectin (*Ławrukajtis-Klimkowska and Ławrukajtis, 1999*). Arabinoxylans strongly influence the quality of bread because their content affects loaf volume, texture of crumb and staling rate (*Biliaderis et al., 1995; Wang et al., 2002*). Addition of arabinoxylans to the dough increases water binding capacity however, it may also contribute to faster retrogradation of starch. Consumption of bread rich in arabinoxylan fraction of dietary fiber reduces both amounts of glucose released to blood stream just after its intake and insulin secretion (*Lu et al., 2000*).

According to Michniewicz et al. (1992) the presence of pentosans hinders formation of intermolecular aggregates of amylose chains in the starch-gluten matrix, which in turn decreases the rate of starch retrogradation and bread staling. Also the enrichment of flour with 2% dry extract of apple pectin improves the quality and freshness of bakery products (*Ballinger, 1992*).

Hydroxypropylmethylcellulose (HPMC) is another additive applied to bakery. Its presence causes a rise in loaf volume, improves crumb texture and decreases the rate of staling of both conventionally baked products (*Armero and Collar, 1996; Rosell et al., 2001; Guarda et al., 2004*) and products obtained via interrupted baking (*Barcenas et al., 2003; Barcenas et al., 2004; Barcenas and Rosell, 2006*). Due to the hydrophilic character HPMC interacts with water (*Sarkar and Walker, 1995; Schiraldi et al., 1996*) and thereby prevents hardening of partially baked bread and slows down hardening of baked bread (*Barcenas and Rosell,2007*).

Apart from the methods described above also other treatments are used to extend the shelf-life of bread and related products. They include the optimization of formulation, flour quality, dough-making process, fermentation conditions, proofing conditions, intensity of mixing, as well as earlier gelatinization of a part of flour before dough preparing and optimization of storage condition (*Ambroziak, 1999*).

Antifungal agents

The growth of microorganisms like toxin-producing filamentous fungi and spore-forming bacteria is one of most important causes of the deterioration of quality of bread and other bakery products. It brings about substantial economic losses to manufacturers and consumers and poses a threat to health of the latter due to potential microbial infection (*Diowksz, 2004*).

Microbial growth causes negative changes in the aroma, taste and texture of bakery products. It may also negatively affect dough fermentation. Principal sources of microbial contamination are flour and environment. Most harmful are *Bacillus* species like *B. cereus*, *B. subtilis,* and *B. polymyxa*, which begin to grow after 24 h of bread storage, and filamentous fungi, which are visible after 2 days of storage. The latter grow optimally at the relative air humidity above 70 % and at temperatures ranging between 20 and 30 °C. Most often encountered fungal contaminants are species of genera: *Aspergillus, Rhizopus, Fusarium* and *Penicillium.*

Noteworthy, almost one third of these fungal species produce toxic secondary metabolites such as mycotoxins, which have a harmful impact on human immunological system, are potential carcinogens and cause the irreversible damage of kidneys. Their examples are: aflatoxins, ochratoxin A, triochothecenes and zearalenones. Mycotoxins are stable at elevated temperature and therefore they are not degraded during baking, which destroy only vegetative forms of microorganisms. Because of these reasons, certain substances extending the shelf-life and inhibiting microbial growth, like chemical preservatives have to be added to baked products. Also leavening prevents the development of pathogenic microflora because the aforementioned lactic acid bacteria inhibit the growth of some other bacteria, yeast and filamentous fungi (*Diowksz, 2004*).

Chemical preservatives used in bread-making are commonly used in food preservation. They cause destruction of cytoplasmic membranes and inhibition of enzymes. Commonly used agents are propionic acid and calcium propionate. Propionic acid is a liquid with unpleasant smell, which inhibits the growth of filamentous fungi and is used in doses below 2 g/kg product (*Chuchlowa, 1996*). It retards the growth of filamentous fungi and germination of *Bacillus* spores, but does not impair yeast development (*Ponte and Tsen, 1987*). Also calcium propionate is used as a preservative but it imparts a weak bitter taste to bread, decreases the activity of yeasts used for leavening and causes faster loss of water by bakery.

According to European Parliament and Council Directive No. 95/2/EC, the level of propionic acid in bread cannot be higher than 3000 ppm (*EU, 1995*). However, recent studies showed that this concentration is not sufficiently high to prevent the growth of bread spoiling microflora (*Lavermicocca et al., 2000; Ryan et al., 2008*). Besides, low levels of chemical preservatives added to baked products may stimulate the growth of fungi (Marin et al. 1999) and biosynthesis of mycotoxins (*Yousef and Marth, 1981; Gareis et al., 1984; Bullerman, 1985*).

Another chemical agent, applicable to bread preservation, is sorbic acid. It is less harmful to consumers' health, does not affect the taste and is more efficient in lower doses compared to propionic acid (*Chuchlowa, 1996*).

Technological process

The quality and shelf-life of bread and related products are also affected by duration and temperature of baking. Differences in texture of the crumb derived from the same dough but baked in different conditions are ascribed to differences in the rates of temperature increase inside the bread core, which depend on heating method and size of baked product.

The structure of crumb is known to depend on the course of gelatinization of starch granules (*Dreese et al., 1988*). The dynamics of temperature growth inside the bread core influences the kinetics and degree of swelling of starch granules, and the extent of changes in the crystallinity of amylopectin and amylose that in turn influence the crumb structure and its alteration during the storage. Bread baked at a high heating rate contains less humidity than bread baked at a lower heating rate. Humidity of bread depends also on heating method, so on the type of baking oven (using hot air or microwaves) (*Patel et al., 2005*). The ultimate humidity level on completion of baking process strongly affects the dynamics of bread ageing (*Walker and Li, 1993; Yin and Walker, 1995; Patel et al., 2005*).

The relatively low rate of heating causes that the enthalpy of amylopectin crystallization is lower, the crumb contains less soluble amylopectin and bread staling is slower (*Patel et al., 2005*). Thus heating rate and method affect attributes of bakery products, together with its staling rate. Differences in bread firmness and the course of its changes during the storage are caused by differences in the degrees of hydration and swelling of starch granules, as well as distribution and aggregation of amylose molecules, which are determined by the rate of heating during baking.

CONCLUSION

Extension of shelf-life of bakery products has been achieved by various methods like: freezing, packaging, thermal processing, bioconservation, chemical agents addition and others.

All these methods are more efficient when appropriate additives are used in manufacturing of bakery products. Some of them like enzymes, leaven, fats, and antifungal agents contribute to elongated shelf-life of these products. They also positively affect technological operations during bread-making and shorten duration of the whole process (e.g. enzymes, leaven, yeast, agents increasing porosity and quality, dairy products, potato products), while some other impart the suitable taste (salt, sugar etc.).

Apart from the improvement of technological characteristics, appropriate additives increase the nutritive value of bakery products. They cause a rise in the content of proteins and exogenous amino acids, unsaturated fatty acids, mineral salts, dietary fiber, and vitamins. This in turn enhances health-promoting effects and renders such bakery products attractive diet components. Particularly attractive additives are: dietary fiber, leavens, and dairy products as well as barley, oats, spelt, and amaranthus – as representatives of cereal grains, which were not used in traditional bread manufacturing.

Application of synthetic additives is caused by the necessity of reducing the time of bread-making process, changing preferences of consumers and the need of inhibition of the growth of microorganisms, mainly filamentous fungi. Their growth excludes bakery products as a food and causes economic losses.

Thus, application of suitable natural and synthetic additives in manufacturing of bakery products may improve their beneficial impact on human health and sensory quality, and extend the shelf-life.

REFERENCES

Akers, A. A., Hoseney, R. C. (1994). Water soluble dextrins from α-amylase-treated bread and their relationship to bread firming. Cereal Chemistry, 71(3), 223-226.

Ambroziak, Z. (1998). Produkcja piekarsko ciastkarska (część 1). WSiP, Warszawa.

Ambroziak, Z. (1999). Produkcja piekarska i ciastkarska (część 2). WSiP, Warszawa.

Armero, E., Collar, C. (1996). Antistaling additive effects on fresh wheat bread quality. Food Science and Technology International, 2 (5), 323–333.

Azzouz, M.A., Bullerman, L.B. (1982). Comparative antimycotic stored with WO pouches was nevertheless not differ- effects of selected herbs, spices, plant components and commercial antifungal agents. Journal of Food Protection, 45, 1298–1301.

Ballinger, H. (1992). Influence of apple pectin extract (APE) on the quality and freshness of baked goods. Food Marketing Technology, 6(4), 6-10.

Barcenas, M. E., Benedito, C., Rosell, C. M. (2004). Use of hydrocolloids as bread improvers in interrupted baking process with frozen storage. Food Hydrocolloids, 18(5), 769–774.

Barcenas, M. E., Haros, M., Rosell, C. M. (2003). An approach to studying the effect of different bread improvers on the staling of prebaked frozen bread. European Food Research and Technology, 218(6), 56–61.

Barcenas, M. E., Rosell, C. M. (2006). Different approaches for improving the quality and extending the shelf life of the partially baked bread: low temperatures and HPMC addition. Journal of Food Engineering, 72(1), 92–99.

Barcenas, M.E., Rosell, C.M. (2007). Different approaches for increasing the shelf life of partially baked bread: Low temperatures and hydrocolloid addition. Food Chemistry, 100(4), 1594–1601.

Berliński Ł., Bońca Z. (2000). Wpływ metod zamrażania produktów żywnościowych na ich cechy jakościowe. Technika Chłodnicza, (8), 335-341.

Bhattacharya, M., Erazo-Castrejón, S.V., Doehlert, D.C., McMullen, M.S. (2002). Staling of bread as affected by waxy wheat flour blends. Cereal Chemistry, 79(2),178–182.

Biliaderis, C. G., Izydorczyk, M. S., Rattan, O. (1995). Effect of arabinoxylans on bread-making quality of wheat flours. Food Chemistry, 53(2), 165–171.

Bullerman, L.B. (1985). Effects of potassium sorbate on growth and ochratoxin production by *Aspergillus ochraceaus* and *Penicillium* species. Journal of Food Protection, 48, 162–165.

Burrington, K.J. (1998). Prolonging bakery product life. Food Product Design, 7, 12-20.

Caballero, P. A., Gomez, M., Rosell, C. M. (2007). Improvement of dough rheology, bread quality and bread shelf-life by enzymes combination. Journal of Food Engineering, 81(1), 42–53.

Ceglińska, A. (2006). Evaluation of the quality of bread. In: Mitek, M., Słowiński, M. (ed.). Selected topics in food technology. (ed). Warsaw, Poland.

Chuchowa, J. (1996). Materiały pomocnicze i dodatki do żywności. WSiP, Warszawa.

Christiansen, L., Vind, J., Borch, K., Heldt-Hansen, H. (2003). Generation of lipases with different specificities and functionalities in breadmaking. In: Courtin, C., Veraverbeke, W., Delcour, J. (ed.). Recent *advances in enzymes in grain processing* Leuven: Katholieke Universiteit Leuven, Belgium.

Collar, C. Armero, E., Martinez, J. (1998). Lipid binding of formula bread doughs. Relationships with dough and bread technological performance. Zeitschrift für Lebenschmitteluntersuchung und Forschung A 207(2), 110-121.

Conner, D.E., Beuchat, L.R. (1984). Effects of essential oils from plants on growth of spoilage yeast. Journal of Food Science, 4 (2), 429–434.

Dal Bello, F., Clarke, C.I., Ryan, L.A.M., Ulmer, H, Schober, T.J., Ström, K., Sjügrend, J., van Sinderen, D., Schnürer, J., Arendt, E.K. (2007). Improvement of the quality and shelf life of wheat bread by fermentation with the antifungal strain Lactobacillus plantarum FST **1.7.** Journal of Cereal Science, 45(3), 309–318.

Davidou, S., Le Meste, M., Debever, E., Bekaert, D. (1996). A contribution to the study of staling of white bread: effect of water and hydrocolloid. Food Hydrocolloids, 10(4), 375-383.

Diowksz, A. (2004). Biokonserwacja pieczywa dzięki zastosowaniu zakwasu. Przegląd Piekarski i Cukierniczy, 53(4), 6-8.

Diowksz, A. (2010a). Pieczywo jako żywność funkcjonalna (cz.I). Przegląd Piekarski i Cukierniczy, 58(9), 18-19.

Diowksz, A. (2010b). Pieczywo jako żywność funkcjonalna (cz.II). Przegląd Piekarski i Cukierniczy, 58(10), 12-14.

Dreese, P.C., Faubion, J.M., Hoseney, R.C. (1988). Dynamic rheological properties of flour, gluten, and gluten–starch doughs. I. Temperature dependent changes during heating. Cereal Chemistry, 65 (4), 348–353.

Drozdowski, B. (2007). Charakterystyka ogólna tłuszczów jadalnych. W: Chemia żywności. Sacharydy, lipidy i białka. Red. Sikorski Z. E. WNT, Warszawa.

Erdogdu-Arnoczky, N., Czuchajowska, Z., Pomeranz, Y. (1996). Functionality of whey and casein in fermentation and in breadbaking by fixed and optimized procedures. Cereal Chemistry, 73(3), 309-316.

European Union, (1995). European Parliament and Council Directive No. 95/2/EC of 20 February 1995 on food additives other than colours and sweeteners.

Fik M. (2004). Czerstwienie pieczywa i sposoby przedłużania jego świeżości. Żywność. Nauka. Technologia. Jakość, 39(2), 5–22.

Fik, M., Michalczyk, M., Surówka, K., Maciejaszek, I. (2000). Characterisation of the staling process of wholemeal bread. Polish Journal of Food Nutrition Science, 9/50(2), 23-28.

Fik, M., Surówka, K., Maciejaszek, I., Macura, M., Michalczyk, M. (2012). Quality and shelf life of calcium-enriched wholemeal bread stored in a modified atmosphere. Journal of Cereal Science 56(2), 418-424.

Gallagher, E., Polenghi, O., Gormley, T.R. (2002). Improving the quality of gluten-free breads. Farm and Food, 12(1), 8-13.

Gareis, M., Bauer, J., von Montgelas, A., Gedek, B. (1984). Stimulation of aflatoxin-B1 and T-2-toxin production by sorbic acid. Applied and Environmental Microbiology, 47(2), 416–418.

Gil, M.J., Callejo, M.J., Rodriguez, G., Ruiz, M.V. (1999). Keeping qualities of white pan bread upon storage: effect of selected enzymes on bread firmness and elasticity. Zeitschrift für Lebenschmitteluntersuchung und Forschung A, 208(5-6), 394-399.

Goesaert, H., Slade, L., Levine, H., Delcour, J.A. (2009). Amylases and bread firming – an integrated view. Journal of Cereal Science, 50(3), 345-352.

Grembecka, M. (2007). Zawartość magnezu, fosforu, cynku i żelaza w różnych gatunkach pieczywa. Bromatologia. Chemia. Toksykologia, 40(4), 319-323.

Guarda, A., Rosell, C. M., Benedito, C., Galotto, M. J. (2004). Different hydrocolloids as bread improvers and antistaling agents. Food Hydrocolloids, 18(2), 241–247.

Guynot, M. E., Sanchis, V., Ramos, J. (2003). Modified Atmosphere Packaging for Prevention of Mold Spoilage of Bakery Products with Different pH and Water Activity Levels. Journal of Food Protection, 66(10), 1864–1872.

Haber, T., Lewczuk, J., Chmielewska, I. (1992). Próby zastosowania lecytyny rzepakowej w piekarstwie. Przegląd Piekarski i Cukierniczy , 40 (2), 6-8.

Haros, M., Rosell, C.M., Benedito, C. (2002). Effect of different carbohydrases on fresh bread texture and bread staling. European Food Research Technology, 215 (5), 425-430.

Hebeda, R.E., Bowles, L.K., Teague, W.M. (1991). Use of intermediate temperature stability enzymes for retarding staling in baked goods. Cereal Foods World, 36 (8), 619-622.

Hoseney, C., Miller, R. (1998). Current understanding of staling of bread. Technical Bulletin, American Institute of Baking Research Department, 20 (6), 1-6.

Jakubczyk, T. (1988). Jakubczyk T. Surowce i materiały pomocnicze w piekarstwie. PWSZ, Warszawa.

Katina, K., Salmenkallio-Marttila, M., Partanen, R., Forssell, P., Autio, K. (2006). Effects of sourdough and enzymes on staling of high-fibre wheat bread. LWT – Food Science and Technology, 39(5), 479–491.

Korus, A., Achremowicz, B. (1994). Substancje stosowane do poprawiania jakości pieczywa. Część II. Związki powierzchniowo czynne oraz inne substancje. Przegląd Piekarski i Cukierniczy, 42(3), 6-7.

Kowalski, S. (2005). Zakwasy piekarskie. Cukiernictwo i Piekarstwo, 9(9), 28-31.

Krog, N., Olesen, S.K., Toernaes, H., Joensson, T. (1989). Retrogradation of the starch fraction in wheat bread. Cereal Foods World, 34, 282-285.

Kweon, M.R., Park, K.H. (1994). Phospholipid hydrolysate and antistaling amylase effects on retrogradation of starch in bread. Journal of Food Science, 59(6), 1072-1080.

Laurikainen, T., Harkonen, H., Autio, K., Poutanen, K. (1998). Effects of enzymes in fibre-enriched baking. Journal of the Science of Food and Agriculture, 76(2), 239–249.

Lavermicocca, P., Valerio, F., Evidente, A., Lazzaroni, S., Corsetti, A., Gobbetti, M. (2000). Purification and characterization of novel antifungal compounds from the sourdough *Lactobacillus plantarum* strain 21B. Applied and Environmental Microbiology, 66(9), 4084–4090.

Le Bail, A., Ribotta, P. (2007). Thermo-physical assessment of bread during staling. Food Science and Technology, 40(5), 879-884.

Lewczuk, J., Sobczyk, M. (1994). Wykorzystanie w piekarstwie sproszkowanej krajowej lecytyny sojowej. Przegląd Piekarski i Cukierniczy, 42(8), 23-25.

Lu, Z. X., Walker, K. Z., Muir, J. G., Mascara, T., Dea, K. (2000). Arabinoxylan fiber, a by-product of wheat flour processing, reduces the postprandial glucose response in normoglycemic subjects. The American Journal of Clinical Nutrition, 71, 1123–1128.

Ławrukajtis-Klimkowska, M., Ławrukajtis, M. (1999). Wpływ pentozanów na cechy reologiczne ciasta z mąki żytniej. Cukiernictwo, 99 (4), 22-26.

Mannie, E., Asp, E.H. (1999). Dairy ingredients for bread baking. Cereal Foods World, 44(3), 143-146.

Marin, S., Sanchis, V., Sanz, D., Castel, I., Ramos, A.J., Canela, R., Magan, N. (1999). Control of growth and fumonisin B1 production by *Fusarium verticillioides* and *Fusarium proliferatum* isolates in moist maize with propionate preservatives. Food Additives and Contaminants, 16, 555–563.

Martin, M.L., Hoseney, R.C. (1991). A mechanism of bread firming. II. Role of starch hydrolyzing enzymes. Cereal Chemistry, 68(5), 503-507.

Marzec, A., Lewicki, P.P., Pietrowska, A. (2007). Badanie procesu czerstwienia pieczywa metodą emisji akustycznej. Żywność. Nauka. Technologia. Jakość, 51(2), 72-79.

Michalska-Pożoga, I., Raczkowska, A. (2011). Pakowanie i inne metody zapobiegania czerstwieniu pieczywa. Ważenie. Dozowanie. Pakowanie, 41(1), 78-81.

Michniewicz, J. (1998). Charakterystyka wybranych grup produktów spożywczych i przykłady pakowania. W: Opakowania żywności. Red. Czerniakowski B. i Michniewicz J. Agro Food Technology, Czeladź.

Michniewicz, J., Biliaderis, C.G., Bushuk, W. (1992). Effect of added pentosans on some properties of wheat bread. Food Chemistry, 43(4), 251-257.

Moayedallaie, S., Mirzaei, M., Paterson, J. (2010). Bread improvers: Comparison of a range of lipases with a traditional emulsifier. Food Chemistry, 122(3), 495–499.

Morgan, K.R., Gerrard, J., Every, D., Ross, M., Gilpin, M. (1997). Staling in starch breads: the effect of antistaling alpha-amylase. Starch/Stärke, 49(2), 54-59.

Nielsen, P.V., Rios, R. (2000). Inhibition of fungal growth on bread by volatile components from spices and herbs, and the possible application in active packaging, with special emphasis on mustard essential oil. International Journal of Food Microbiology, 60(2-3), 219–229.

Patel, B.K., Waniska, R.D., Seetharam, K. (2005). Impact of different baking processes on bread firmness and starch properties in breadcrumb. Journal of Cereal Science, 42(2), 173–184.

Piesiewicz, H. (2005). Wzrost znaczenia kultur starterowych. Przegląd Piekarski i Cukierniczy, 53, 14-17, 24.

Polak, E., Ćwiertniewski, K., Egierski, K. (2004). Wpływ warunków zamrażania na jakość pieczywa pszennego. W: Żywność aspekty technologiczne i prozdrowotne. XXXV Sesja Naukowa Komitetu Nauk o Żywności Polskiej Akademii Nauk Łódź, 5a/36.

Ponte, J.G., Tsen, C.C. (1987). Bakery products, In: Food and Beverage Mycology, Beuchat, L. (ed.) AVI, New York, N.Y.

Postolski, J. (2002). Postolski J. Nowoczesne technologie zamrażania pieczywa i wyrobów cukierniczych. Technika Chłodnicza i Klimatyzacyjna, 2, 47-53.

Olesen, T., Qi Si, J., Donelyan, V. (1994). Use of lipase in baking. International Patent Application WO 94/04035.

Qi Si, J., Drost-Lustenberger, C. (2002). Enzymes for bread, pasta and noodle products. In: Enzymes in Food Technology. Whitehurst, R.J., Law, B.A. (Ed.). Sheffield Academic Press CRC Press UK.

Rosell, C. M., Rojas, J. A., Benedito de Barber, C. (2001). Influence of hydrocolloids on dough rheology and bread quality. Food Hydrocolloids, 15(1), 75–81.

Rouau, X., El-Hayek, M.L., Moreau, D. (1994). Effect of an enzyme preparation containing pentosanases on the bread-making quality of flours in relation to changes in pentosan properties. Journal of Cereal Science, 19(3), 259-272.

Ryan, L.A.M., Dal Bello, F., Arendt, E.K. (2008). The use of sourdough fermented by antifungal LAB to reduce the amount of calcium propionate in bread. International Journal of Food Microbiology, 125(3), 274–278.

Sarkar, N., Walker, L. C. (1995). Hydration–dehydration properties of methylcellulose and hydroxypropylmethylcellulose. Carbohydrate Polymers, 27, 177–185.

Scanlon, M.G., Sapirstein, H.D., Fahloul, D. (2000). Mechanical properties of bread crumb prepared from flours of different dough strength. Journal of Cereal Science, 32(3), 235-243.

Schiraldi, A., Piazza, L., Riva, M. (1996). Bread staling: a calorimetric approach. Cereal Chemistry, 73(1), 32–39.

Shelef, L.A. (1983). Antimicrobial effect of spices. Journal of Food Safety, 6, 29-44.

Skotnicka, M., Palich, P. (2007). Wpływ warunków przechowywania na stopień czerstwienia mrożonych wyrobów ciastkarskich. Żywność. Nauka. Technologia. Jakość, 54(5), 84-92.

Soral-Śmietana, M. (1989). Interakcje skrobia-tłuszczowce w kształtowaniu jakości pieczywa. Przegląd Piekarski i Cukierniczy, 37(2), 17-19.

Spendler, T., Christiansen, L., Frandsen, T. (2001). Functionality and mechanism of a new 2nd generation lipase for the baking industry. In 2001 AACC annual meeting. Charlotte, North Carolina: American Association of Cereal Chemists.

Tenkanen, M., Salmenkallio-Marttilla, M., Poutanen, K. (1998). Baking with enzymes. What makes it happen? World of Ingredients 5/6, 38-41.

Van Dam, H.W., Hille, J.D.R. (1992). Yeast and enzymes in bread making. Cereal Foods World, 37, 245-252.

Walker, C.E., Li, A. (1993). Impingement oven technology. III. Combining impingement with microwave (hybrid oven). Technical Bulletin, American Institute of Baking Research Department, 15, 1–6.

Włodarczyk, M., Diowksz, A.(1998). Piekarskie kultury starterowe – szansa zdrowotna i ekonomiczna. Przegląd Piekarski i Cukierniczy, (8), 5-7.

Wojciechowicz, A., Gil, Z. (2009) Jakość pieczywa pszennego z udziałem błonnika pokarmowego różnego pochodzenia. Żywność. Nauka. Technologia. Jakość, 67(6), 102-111.

Yaseen, A.A.E., Shouk, A.A., Sadowska, J., Fornal, J., Jeliński, T. (2001). Effect of pectin and α-amylase on the microstructure and staling of bread. Polish Journal of Food Nutrition Science, 10/51(4), 19-25.

Yi, J., Kerr, W. L. (2009). Combined effects of dough freezing and storage conditions on bread quality factors. Journal of Food Engineering, 93(4), 495–501.

Yin, Y., Walker, C.E. (1995). A quality comparison of breads baked by conventional versus nonconventional ovens – A review. Journal of the Science of Food and Agriculture, 67(3), 283–291.

Yousef, A. E., Marth, E.H. (1981). Growth and synthesis of aflatoxin by *Aspergillus parasiticus* in the presence of sorbic acid. Journal of Food Protection, 44, 736–741.

Zaika, L. L. (1988). Spices and herbs: their antimicrobial activity and its determination. Journal of Food Safety, 9, 97–118.

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