Scientific Bulletin. Series F. Biotechnologies, Vol. XXIV, No. 2, 2020
ISSN 2285-1364, CD-ROM ISSN 2285-5521, ISSN Online 2285-1372, ISSN-L 2285-1364

PACKAGING AND TECHNOLOGICAL SOLUTIONS FOR BREAD SHELF LIFE IMPROVING

Șerban-Eugen CUCU[1, 2], Mona Elena POPA[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest, Faculty of Biotechnologies, 59 Mărăști Blvd, District 1, Bucharest, Romania
[2]National Institute of Research and Development for Food Bioresources - IBA Bucharest, 5 Ancuța Băneasa Street, District 2, Bucharest

Corresponding author email: serban2serban@yahoo.com

Abstract

Bread shelf life in our society is a problem if we look in food waste zone. In the studies of bread shelf-life, an important role is carried out by the various packaging materials and technological solutions that exist. Traditionally, packaging materials had to be as inert as possible (this method is so-called passive packaging), and because of this bread was protected against the main causes of spoilage, namely the presence of oxygen and mold. Most recent, films made of synthetic polymers that have low gas permeability, coupled with the modification of the packaging headspace through decreasing oxygen levels below 0.1% and also the use of a new concept called active packaging that allows the packaging material to interact with the food products, thus improving the bread shelf-life drastically. The new concepts of active packaging and intelligent packaging, in which the new developed functional materials deliberately interact with bread in order to prolong or monitor the shelf life and the use of nanomaterials represent the top of innovation in this field. Technological aids such as natural antimicrobial compounds or sourdough utilization can be very useful tools used to improve bread quality and shelf life. Finding adequate bread packaging systems, in addition with technological interventions on formulation and breadmaking technologies, can increase significantly bread shelf life. This paper will review the literature for various state of the art packaging and technological solutions for bread shelf life and quality improving.

Key words: *bread packaging, shelf life, natural antimicrobials, sourdough.*

INTRODUCTION

The shelf life of cereal products and their derivates, can be in general influenced by the packaging materials and used technologies, with special regards in our case, bread it is mainly dependent on the staling rate (Cencic et al., 1996; Del Nobile et al., 2003; Fava et al., 2000; Lanza et al., 2000; Latou et al., 2010; Licciardello et al., 2013; Pagani et al., 2006; Piergiovanni & Fava, 1997; Rodríguez et al., 2000). Shelf life testing represents a tool for selecting the most suitable packaging systems. The bread staling is a complex phenomenon, which cannot be described by only one parameter (Karim et al., 2000, Sidhu et al., 1997). For the reason mentioned above, various tests are usually performed simultaneously and supplying complementary information which can be associated with bread staling. Karim et al. (2000) reviewed the methods for the study of starch retrogradation, which include based on the changes in physical and chemical properties. In the last years, both producers and consumers have become more sensitive towards the sustainability of food production, with some special regards for the role of packaging. Estimations of the impact of packaging are in the range of 5–10% of the total environmental impact of a food item (Hanssen, 1998). Sometimes it is necessary to increase the packaging environmental impact in order to reduce food losses (Wikström & Wilsson, 2010). This is not always true and new packaging solutions that have a lower environmental impact can be able to guarantee certain shelf life standards.
Bread is considered to be a fundamental food product and it is generally viewed as a perishable commodity, due to its fast decrease of freshness features and due to its rapid staling (Minervini et al., 2014). Bread is always present

in the human daily diet, being one of the main produced products of Romanian food industry. The annual average consumption of bread per capita, is estimated at 97 kg/capita, exceeding the European average consumption levels. About 55% of the Romanian households consume unpacked bread, acquired mainly from small supermarkets and bakeries (Tamba-Berehoiu et al., 2014). Bakery products made by using highly refined white flour contain lower amounts of vitamin B1 and vitamin E compared with those containing whole-wheat flour or rye flour. Addition of supplementary ingredients (olive oil, garlic, onion, mixed seeds) to some types of bakery products resulted in obtaining B1 and E vitamins enriched food products. These supplementary vegetal ingredients were used to improve the taste and to diversify the range of bakery products, aiming to be an encouragement and an orientation for healthier food consumption. (Gherghina et al., 2015). Lactic acid bacteria (LAB) and yeasts in the form of sourdough have been reported to have positive effects on wheat bread quality and staling (Clarke et al., 2002; Corsetti et al., 2000; Crowley et al., 2002) as they are responsible for the capacity of dough to leaven, while acidifying it (De Vuyst & Neysen, 2005). Traditional sourdough obtained with selected microorganisms is able to increase bread shelf life by delaying staling (Chavan & Chavan, 2011) and improve bread properties through enhancing its nutritional value, taste, and aroma profile (Arendt et al., 2007; Hansen & Schieberle, 2005; Poutanen et al., 2009). The use of LAB may affect the rheology of leavened bakery products through a strain-dependent proteolytic activity (Gobbetti et al., 1996).

Modified atmosphere packaging (MAP) is one of the methods used to extend product shelf life. This can be done by using different gases to replace air around non-respiring foods regardless of whether or not the atmosphere changes over time of storage or packing. The most used MAP technique used for bakery products is the addition of CO_2 inside the food packaging in order to decrease the O_2 levels. In this way the shelf-life of the MAP packaged products will be prolongedIn high water content food like bakery products, CO_2 can dissolve in water to form carbonic acid, thus lowering the pH. This acidification of the cell contents causes the death of bacteria. It is concluded that mold growth could not be prevented but could be delayed by N_2 and/or CO_2 up to 5-10 days (Smith et al., 1986). The only possibility to prevent mold growth was to maintain the level of O_2 below 0.4%. Results of the dependency of O_2 content on fungi growth on other types of products under MAP were confirmed. A study carried out by Marta Taniwaki about the use of modified atmospheres to prevent fungal growth and mycotoxin production in cheese was evaluated. Eight fungal species: *Mucor plumbeus*, *Fusarium oxysporum*, *Byssochlamys fulva*, *Byssochlamys nivea*, *Penicillium commune*, *Penicillium roqueforti*, *Aspergillus flavus* and *Eurotium chevalieri* were inoculated onto cheese samples and incubated under conditions of decreasing concentrations of O_2 (0.5% to 5%) and increasing concentrations of CO_2 (20-40%). Fungal growth was measured by colony diameter and ergosterol content. All fungi examined grew in atmospheres containing 20% and 40% CO_2 with 1% or 5% O_2, and growth was reduced by 20-80%, depending on species, compared with growth in air (Stamatiset al., 2007; Halouat et al., 1997; Sanguinetti et al., 2016; Taniwaki et al., 2001). However, the high concentration of CO_2 may lead to increased perceived acidity in the organoleptic proprieties (Fik et al., 2012; Suppakul et al., 2016). Furthermore, the conclusive effect of CO_2 in the MAP on the bread nutritional quality currently cannot be made due to conflicting results from various researches. Another packaging technique that has been studied is active packaging (AP), in which the packages not only act as a protective barriers but also interact with the packaged product in order to protect it from adulteration, for example, moisture, oxygen, ethylene, and microorganisms.

Two types of AP, i.e. sachet-based and plastic film-based packaging, have been developed for food industry. Sachets, containing active ingredients such as oxygen absorbers, ethylene scavengers, and moisture absorbers, were developed in the late 1970s in Japan. Although this technique is considerably practical for packaging industries, some disadvantages are inevitable. They cannot be used in liquid products or in the tight-fitting film as their functionalities would be restrained. Furthermore, risks of accidental ingestion of these sachets are a serious concern. These drawbacks can be alleviated if those functionality components are incorporated in the packaging material matrix itself. In addition to that, recent studies have revealed that combinations of various packaging techniques to prolong shelf life are more effective. The study of Berenzon and Saguy (1998) suggested that even though using oxygen absorber sachets was very effective in terms of controlling the headspace oxygen, they could not slow down lipid oxidation of crackers when stored at high temperatures, attaining comparable sensory evaluation of crackers kept in absence of oxygen absorber sachets. An oxygen absorber sachet was found to extend the shelf life of pita bread and bakery products by impeding mold and yeast growth even in CO_2/N_2 MAP due to the fact that it absorbed oxygen trapped in food and in the air that permeated through the package (Smith et al., 1986).

MATERIALS AND METHODS

Web of Science database was electronically searched for articles published in the last decades. The literature search included as documents research articles and reviews. Keywords used were: “sourdough”, “packaging in bread industry”, “bread making”, “bread shelf life” while the articles title contained the word “flour”.

RESULTS AND DISCUSSIONS

Baked products are perishable foods that undergo severe physical, physiochemical, organoleptic and microbial changes during storage (Robertson, 1993). The time-dependent loss in quality of flavor and texture is generally described as bread staling. Crumb firmness significantly increases, crispness of the bread crust decreases, and the bread loaf loses its fragrance, assuming a stale flavor. These complex physical and chemical phenomena are a consequence of a retrogradation of the starch granules gelatinized during baking, an interchange of moisture between the starch and protein constituents of bread, an increase in interaction between the protein fraction and starch, a redistribution of water in bread and a removal of aromatic molecules (Parker & Ring, 2001; Piazza & Masi, 1995; Schiraldi & Fessas, 2001). The use of sourdough has a long tradition and still plays an important role in the bread-making process. Sourdough is obtained by spontaneous fermentation of a mixture of flour, water and salt; recent years have seen the use of specific cultures and control of the fermentation process. Sourdough is used in baking and its ability to improve the quality and extend the shelf life of bread has been widely studied (Arendt et al., 2007; Gocmen et al., 2007; Katina et al., 2006; Martinez-Anaya, 2003). The impact of processing conditions on the microbial quality of par-baked wheat and sourdough bread was investigated by Debonne et al. (2017). Processing conditions included par-baking time (8 and 13 min), temperature (150 and 200 °C), amount of steam (200 and 600 mL), and the use of MAP. Total anaerobic mesophilic plate counts, moulds, yeasts and spore-forming bacteria, together with pH (power of hydrogen) and a_w (water activity) of the par-baked breads were analysed. The obtained data was used to make predictive models showing the impact of the main effects and their interactions. Sourdough addition could extend the time of acceptable bread quality based on the anaerobic counts from 8 to more than 13 days. Visual growth of moulds and yeasts (presence/absence of single spots) was most efficiently obtained by the combination of MAP and the use of highest baking temperature and time. Microbiological analysis of moulds and yeasts however, showed that sourdough had the best preservation potential, followed by MAP. This study showed that adjusting the par-baking conditions, bread composition and packaging can increase the shelf-life of par-baked bread in a natural way. (Els Debonne et al., 2018).

Lactic acid bacteria (LAB) constitute a heterogeneous group of industrially important bacteria that are used to produce fermented foods and beverages, using various substrates, such as milk, vegetables, cereals, meat, cocoa beans etc. The most important advantage of LAB, making them suitable for the use in food biotechnology, is that they are generally recognized as safe (GRAS - Generally

Recognized as Safe). LAB have been shown to contribute to the improvement of the shelf life of fermented foods, due to the production of a wide variety of compounds, acting in a synergistic way to prevent or eliminate microbial contamination.

In fermented foods, LAB also contributes to the nutritional and organoleptic characteristics of the final products and they are traditionally used as starter cultures for the industrial production of many types of foods and beverages.

The so-called "functional foods" concept was recently proposed and has shown a remarkable growth over the last few years. Such foods should promote well-being and health improvements, while at the same time should reduce the risk of some major chronic and degenerative diseases, such as cancer, cardiovascular diseases, obesity and gastrointestinal tract disorders (Zamfir M. et al., 2014).

Lactic acid bacteria (LAB) produce several metabolites which have been shown to have a positive effect on the texture and staling of bread, e.g. organic acids, exopolysaccharides (EPS) and/or enzymes. EPS can improve the viscoelastic properties of dough, increase loaf volume, reduce crumb hardness and prolong shelf life (Poutanen et al., 2009; Tieking & Gänzle, 2005). Moreover, the transformation of amino acids or peptides to aroma compounds contributes substantially to food flavor. In particular, the conversion of glutamate by LAB enables the targeted optimization of food flavour (Gänzle, 2009; Plessas et al., 2011). *In situ* production of EPS has the advantage of avoiding the use of bread improvers such as expensive hydrocolloids (Arendt et al., 2007; Palomba et al., 2012; Pepe et al., 2013; Tieking et al., 2003). However, *in situ* production of exopolysaccharides during sourdough fermentation is challenged by simultaneous acidification due to metabolic activities of the bacteria, which may significantly diminish the positive technological impact of EPS (Katina et al., 2009). Formation of alternative products from sucrose like organic acids are of special importance for application of *in situ* produced EPS. Lactate and acetate have previously been identified to significantly affect dough rheology, bread volume and crumb hardness, and may counterbalance the positive effect of EPS (Kaditzky & Vogel, 2008). Lacaze et al. (2007) have developed a new process used to obtain a dextran-rich sourdough by using a specific LAB strain (*Leuconostoc mesenteroides* LMGP-16878) able to produce a enough high molecular weight (HMW) dextran, ensuring a significant impact on bread volume.

The sourdough obtained allows improvements in freshness, crumb structure, mouth feel and softness of all kinds of baked goods from wheat-rich dough products to rye sourdough breads. Katina et al. (2009) showed the potential of *Weissella confusa* to produce significant amounts of polymeric dextran and isomaltooligo-saccharides in wheat sourdough without strong acidification. Dextran-enriched *W. confusa* sourdoughs showed increased viscosity and improved bread quality. Di Cagno et al. (2006) reported that the synthesis of EPS was found from sucrose only as shown by carbohydrate consumption, Moreover, compared with EPS-negative strain (*Lactobacillus sanfranciscensis* SF17), sourdough started with EPS positive strains (*Weissella cibaria* WC4, *Lactobacillus plantarum* PL9), fermented at 30°C for 24 h, increased its viscosity, and the resulting bread had higher specific volume and lower firmness. The performance of *L. sanfranciscensis* TMW 1.392 and its levansucrase deletion mutant in wheat dough and their impact on bread quality was studied by Kaditzky, et al. (2008). The authors reported that *in situ* production of EPS was not enough to achieve the same positive effects of EPS, as they partially overlapped with effects resulting from enhanced acidification. LAB strains and/or fermentation conditions must be found to maximize *in situ* EPS production while at the same time optimizing acid production to a certain quotient which allows acceptable volume, crumb structure and flavor of breads. Thus, when EPS-producing strains are screened for dough applications, their metabolite pattern, the pH at the end of fermentation and fermentation quotient (the molar ratio of lactate/acetate) should be considered.

CONCLUSIONS

Advanced packaging technologies have been playing an important role in food industries for more than a decade and becoming more and more common in recent years especially in a health-concerned society. As these types of packaging technologies successfully extend the shelf life for several foodstuffs including bakery products, uses of chemical preservatives which cause health hazard problems can be reduced significantly.

Food packages are required to have multi-functions in terms of chemical, physical, and biological alterations of the food to prolong its shelf life. Chemically, the packages should be able to control and/or prevent oxidation and some other chemical reactions, such as hydrolytic rancidity and Maillard reaction, in food products. Packages should maintain the moisture level in the products which is a critical parameter in controlling bread staling and changes in texture and physical appearance. Most importantly, microbial growth in food during storage is a serious problem and a major cause to shorten food shelf life. Packages that can inhibit microbial proliferation are currently in demand. The use of sourdough in bread-making influences all aspects of bread quality. Technological effects of the sourdough on flavor, texture, shelf life, and nutritional quality of products depends on the bioconversion of flour components at dough stage (Gänzle M. G., 2014). Apart from generating a unique flavor, the products of sourdough fermentation have been linked to various health benefits (Poutanen et al., 2009).

REFERENCES

Arendt, E. K., Ryan, L. A., Dal Bello, F. (2007). Impact of sourdough on the texture of bread. *Food Microbiology*, 24(2), 167-174.

Berenzon, S., & Saguy, I. S. (1998). Oxygen absorbers for extension of crackers shelf-life. *LWT Food Sci. Technol.*, 31 (1), 1-5.

Cencic, L., Bressa, F., Dalla Rosa, M. (1996). Influence of modified atmosphere on bread staling during storage. *Italian Food & Beverage Technology*, 71, 20-24.

Chavan, R. S., & Chavan, S. R. (2011). Sourdough technology-a traditional way for wholesome foods: A review. *Comprehensive Reviews in Food Science and Food Safety*, 10(3), 169-182.

Clarke, C. I., Schober, T. J., Arendt, E. K. (2002). Effect of single strain and traditional mixed strain starter cultures on rheological properties of wheat dough and on bread quality. *Cereal Chemistry Journal*, 79(5), 640-647.

Corsetti, A., Gobetti, M., De Marco, B., Balestrieri, F., Paoletti, F., Russi, L. (2000). Combined effect of sourdough lactic acid bacteria and additives on bread firmness and staling. *Journal of Agricultural and Food Chemistry*, 48(7), 3044-3051.

Crowley, P., Schober, T. J., Clarke, I. C., Arendt, E. K. (2002). The effect of storage time on textural and crumb grain characteristics of sourdough wheat bread. *European Food Research and Technology*, 214, 489-496.

De Vuyst, L., & Neysen, P. (2005). The sourdough microflora: Biodiversity and metabolic interactions. *Trends in Food Science & Technology*, 16, 43-56.

Debonne, E., Van Bockstaele, F., Philips, E., De Leyn, I., & Eeckhout, M. (2017). Impact of par-baking and storage conditions on the quality of par-baked and fully baked bread. LWT-Food *Science and Technology*, 78, 16-22.

Debonne, E., Bockstaele, F. V., Driessche, M. V., De Leyn, I., Eeckhout, M., Devlieghere, F. (2018). Impact of par-baking and packaging on the microbial quality of par-baked wheat and sourdough bread, *Food Control*, 91, 12-19.

Del Nobile, M.A., Martoriello, T., Cavella, S., Giudici, P., Masi, P. (2003). Shelf life extension of durum wheat bread. *Italian Journal of Food Science,* 15(3), 383-393.

Di Cagno, R., De Angelis, M., Limitone, A., Minervini, F., Carnevali, P., Corsetti, A., Gaenzle M, Ciati R, Gobbetti M. (2006). Glucan and fructan production by sourdough Weissella cibaria and Lactobacillus plantarum. *Journal of Agricultural and Food Chemistry*, 54, 9873-9881.

Di Cagno, R., Gobbetti, M. (2014). Ecological parameters influencing microbial diversity and stability of traditional sourdough. *International Journal of Food Microbiology*, 3(171), 136-146.

Fava, P., Limbo, S., Piergiovanni, L. (2000). La previsione della shelf life di prodotti alimentari sensibili agli scambi di umidità. *Industrie Alimentari*, 39, 121-128.

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.

Gänzel, M. G. (2009). From gene to function: metabolic traits of starter cultures for improved quality of cereal foods. *International Journal of Food Microbiology*, 134, 29-36.

Gänzle M. G. (2014). Enzymatic and bacterial conversions during sourdough fermentation, *[J] Food Microbiology*, 37, 2-10.

Gherghina E., Israel-Roming F., Balan D., Luta G., Simion V., Zachia M. (2015). Assessment of some nutrients in bakery products. *Scientific Bulletin. Series F. Biotechnologies*, Vol. XIX, 140-144.

Gobbetti, M., Smacchi, E., & Corsetti, A. (1996). The proteolytic system of Lactobacillus sanfrancisco CB1: Purification and characterization of a proteinase, a dipeptidase, and an aminopeptidase. *Applied and Environmental Microbiology*, 62(9), 3220-3226.

Gocmen, D., Gurbuz, O., Kumral, A. Y., Dagdelen, A. F., & Sahin, I. (2007). The effects of wheat sourdough on glutenin patterns, dough rheology and bread properties. *European Food Research and Technology*, 225, 821-830.

Halouat, A. E., & Debevere, J. M. (1997). Effect of water activity, modified atmosphere packaging and storage temperature on spore germination of moulds isolated from prunes. *International Journal Food Microbiology*, 35(1), 41-48.

Hanssen, O. J. (1998). Environmental impacts of product systems in a life cycle perspective: A survey of five product types based on life cycle assessments studies. *Journal of Cleaner Production*, 6(3-4), 299-311.

Hansen, A., & Schieberle, P. (2005). Generation of aroma compounds during sourdough fermentation: Applied and fundamental aspects. *Trends in Food Science & Technology*, 16, 85-94.

Kaditzky, S., & Vogel, R. F. (2008). Optimization of exopolysaccharide yield in sourdoughs fermented by lactobacilli. European *Food Research and Technology*, 228, 291-299.

Kaditzky, S., Seitter, M., Hertel, C., & Vogel, R. F. (2008). Performance of *Lactobacillus sanfranciscensis* TMW 1.392 and its levansucrase deletion mutant in wheat dough and comparison of their impact on bread quality. *European Food Research and Technology*, 227, 433-442.

Karim, A., Norziah, M., Seow C. (2000). Methods for the study of starch retrogradation. *Food Chemistry*, 71, 9-36.

Katina, K., Heinio, R. L., Autio, K., & Poutanen, K. (2006). Optimization of sourdough process for improved sensory profile and texture of wheat bread. *LWT - Food Science and Technology*, 39, 1189-1202.

Katina, K., Maina, N. H., Juvonen, R., Flander, L., Johansson, L., Virkki, L., et al. (2009). In situ production and analysis of *Weissella confusa* dextran in wheat sourdough. *Food Microbiology*, 26, 734-743.

Lacaze, G., Wick, M., & Cappelle, S. (2007). Emerging fermentation technologies: development of novel sourdoughs. *Food Microbiology*, 24, 155-160.

Lanza, C. M., Tomaselli, F., Muratore, G., Pulvirenti A. (2000). Study on shelf-life of a pastry for ice-cream. *Industrie Alimentari*, 39(392), 565-571.

Latou, E., Mexis, S., Badeka, A., Kontominas M. (2010). Shelf life extension of sliced wheat bread using either an ethanol emitter or an ethanol emitter combined with an oxygen adsorber as alternatives to chemical preservatives. *Journal of Cereal Science*, 52, 457-465.

Licciardello, F., Rizzo, V., Grillo, O., Venora, G., Muratore, G. (2013). Bread-making performances of durum wheat semolina, as affected by ageing. *Journal of Cereal Science*, 57(3), 372-376.

Martinez-Anaya, M. A. (2003). Association and interaction of microorganisms in dough fermentations: effects on dough and bread characteristics. *Handbook of dough fermentations*, New York: Marcel Dekker, 63-95. Minervini, F., De Angelis, M.

Pagani, M., Lucisano, M., Mariotti, M., Limbo S. (2006). Influence of packaging material on bread characteristics during ageing. *Packaging Technology and Science*, 19(5), 295-302.

Palomba, S., Cavella, S., Torrieri, E., Piccolo, A., Mazzei, P., Blaiotta, G., et al. (2012). Wheat sourdough from Leuconostoc lactis and Lactobacillus curvatus exopolysaccharide-producing starter culture: polyphasic screening, homopolysaccharide composition and viscoelastic behavior. *Applied and Environmental Microbiology*, 78(8), 2737-2747.

Parker, R., & Ring, S. G. (2001). Macromolecular aspect of bread staling. *Series in contemporary food science Bread staling,* New York: CRC Press LLC. 61-71.

Piergiovanni, L., Fava, P. (1997). Minimizing the residual oxygen in modified atmosphere packaging of bakery products. *Food Additives and Contaminants*, 14(6-7), 765-773.

Pepe, O., Ventorino, V., Cavella, M., Fagnano, M., & Brugno, R. (2013). Prebiotic content of bread prepared with flour from immature wheat grain and selected dextran-producing lactic acid bacteria. *Applied and Environmental Microbiology*, 79, 3779-3785.

Piazza, L., & Masi, P. (1995). Moisture redistribution throughout the bread loaf during staling and its effect on mechanical properties. *Cereal Chemistry*, 72(3), 320-325.

Plessas, S., Alexopoulos, A., Bekatorou, A., Mantzourani, I., Koutinas, A. A., & Bezirtzoglou, E. (2011). Examination of freshness degradation of sourdough bread made with kefir through monitoring the aroma volatile composition during storage. *Food Chemistry*, 124, 627-633.

Poutanen, K., Flander, L., & Katina, K. (2009). Sourdough and cereal fermentation in a nutritional perspective. *Food Microbiology*, 26, 693-699.

Robertson, G. L. (1993). Food packaging - Principles and practice. New York, USA. Marcel Dekker, Inc.

Rodríguez, M., Medina, L. M., Jordano, R. (2000). Effect of modified atmosphere packaging on the shelf life of sliced wheat flour bread. *Nahrung*, 44(4), 247-252.

Sanguinetti, A. M., Del Caro, A., Scanu, A., Fadda, C., Milella, G., Catzeddu, P., Piga, A. (2016). Extending the shelf life of gluten-free fresh filled pasta by modified atmosphere packaging. *LWT - Food Sci. Technol*., 71, 96-101.

Schiraldi, A., & Fessas, D. (2001). Mechanism of staling: an overview. In P. Chinachoti, & Y. Vodovotz (Eds.), *Series in contemporary food science Bread staling.* CRC Press LLC.

Sidhu, J. S., Al-Saqer, J., Al-Zenki, S. (1997). Comparison of methods for the assessment of the extent of staling in bread. *Food Chemistry*, 1-2, 161-167.

Smith, J. P., Ooraikul, B., Koersen, W. J., Jackson, E. D., Lawrence, R. A. (1986). Novel approach to oxygen control in modified atmosphere packaging of bakery products. *Food Microbiology*, 3(4), 315-320.

Stamatis, N., Arkoudelos, J. (2007). Quality assessment of Scomber colias japonicus under modified atmosphere and vacuum packaging. *Food Control*, 18 (4), 292-300.

Suppakul, P., Thanathammathorn, T., Samerasut, O., Khankaew S. (2016). Shelf life extension of “fios de ovos”, an intermediate-moisture egg-based dessert, by active and modified atmosphere packaging. *Food Control*, 70, 58-63.

Tamba-Berehoiu, R., Popa, C., Vișan, L., Popescu, S. (2014). Correlations between the quality parameters and the technological parameters of bread processing, important for product marketing. *Romanian Biotechnological Letters*, 19(3).

Taniwaki, M. H., Hocking, A. D., Pitt, J. I., Fleet, G. H. (2001). Growth of fungi and mycotoxin production on cheese under modified atmospheres. *International Journal Food Microbiology*, 68(1-2), 125-133.

Tieking, M., Korakli, M., Ehrmann, M. A., Gänzle, M. G., & Vogel, R. F. (2003). *In situ* production of exopolysaccharides during sourdough fermentation by cereal and intestinal isolates of lactic acid bacteria. *Applied and Environmental Microbiology*, 69, 945-952.

Tieking, M., & Gänzle, M. (2005). Exopolysaccharides from cereal - associated lactobacilli. *Trends in Food Science and Technology*, 79-84.

Wikström, F., & Wilsson, H. (2010). Potential environmental gains from reducing food losses through development of new packaging - A Life-Cycle model. *Packaging Technology and Science*, 23, 403-411.

Zamfir M., Cornea C. P., De Vuyst L., Grosu T. S. S. (2014). Biodiversity and biotechnological potential of lactic acid bacteria. *AgroLife Scientific Journal*, Volume 3, Number 1, ISSN 2285-5718, 169-176.