Scientific Bulletin. Series F. Biotechnologies, Vol. XXVII, No. 1, 2023
ISSN 2285-1364, CD-ROM ISSN 2285-5521, ISSN Online 2285-1372, ISSN-L 2285-1364

TECHNOLOGIES FOR SOURDOUGH OBTAINING, FERMENTATION AND APPLICATIONS – A REVIEW

Sabina-Andreea BOBEA[1, 2], Nastasia BELC[1, 2], Călina Petruța CORNEA[1]

[1]University of Agronomic Sciences and Veterinary Medicine of Bucharest,
59 Mărăști Blvd, District 1, 011464, Bucharest, Romania
[2]National Research & Development Institute for Food Bioresources - IBA Bucharest,
6 Dinu Vintilă Street, District 2, 021102, Bucharest, Romania

Corresponding author email: sabina.bobea@bioresurse.ro

Abstract

Recent trends are towards long-life, nutritious, preservative-free products that improve immunity, digestion and well-being and are tailored to nutritional needs and lifestyle of the consumer. In this perception, sourdough bread is part of this product category. The sourdough has a key role in obtaining a product with sensory properties such as: color, flavor, taste, texture even bread volume. The microflora is dominated by lactic acid bacteria and yeast, very important elements when we talk about the fermentation of bread dough. The factors influencing dough quality are: dough yield, temperature, microflora, environmental acidity and substrate. Dough can be classified into 3 types, of which the most used in the bakery industry is Type III. The beneficial contribution that this type of fermentation brings is not only to increase the volume of the bread, the flavor and the nutritional value, but also to extend the shelf life by inhibiting spoilage bacteria.

Key words*: lactic acid bacteria, yeast, sourdough technology, fermentation.*

INTRODUCTION

The sourdough dates back to antiquity (in the murals of the Egyptian civilization from 1500 BC). With the introduction of baker's yeast to the market (starting in the 19th century), consumer preferences shifted towards yeast bread, while in the recent years the trend has been towards sourdough bread. (https://bakerpedia.com/the-technology-of-sourdough-starters/)

The sourdough is a product obtained both in artisan bakeries and on a large scale, at the industrial level. Manufacturers supply the yeast either with starter for their own dough production or with fully fermented sourdough. Among these products are dry doughs, which are produced mainly from rye and wheat flour, but also from other plants containing starch, such as pseudocereals or legumes (Brandt, 2019).

Flour, water, salt, yeast and lactic acid bacteria cultures are needed to obtain the sourdough (Park et al., 2019). The microbiota of a certain dough can be influenced by its geographical origin, so the interpretation of research data depends on sampling, isolation and identification procedures (De Vuyst et al., 2017).

MATERIALS AND METHODS

The present paper is based on the research of the sourdough production and fermentation technologies, accessing the recently published articles on the e-nformation platform through keywords (lactic acid bacteria, yeast, sourdough technology, fermentation).

RESULTS AND DISCUSSIONS

From a microbiological perspective, the sourdough used in bakery production represents an ecosystem made up of yeasts and lactic acid bacteria. The last one has a role in the acidification of the dough, and in combination with the yeasts, help to form the aroma. Both yeasts and lactic acid bacteria of the heterofermentative type are needed for leavening.

Lactic acid bacteria (LAB) are part of the group of probiotics considered generally as safe elements (GRAS) for health with multiple benefits, such as: preventing the growth of

pathogens, immunomodulators, anticancer effects, improving the symptoms of lactose intolerance, reducing cholesterol levels, preventing and alleviating diarrheal symptoms (Kumar R. and Dhanda S., 2017; Nazir Y. et al., 2018).

During the sourdough-making process, a double-acting phenomenon occurs: the lactic acid bacteria multiply, and the pH drops with the subsequent hydrolysis of starch and proteins, favoring the growth of yeasts. At the same time, the yeast releases amino acids during autolysis, thus contributing to the growth of lactic bacteria. There is a synergistic growth of the lactic acid bacteria and yeasts used in the fermentation process, ultimately resulting in a product with a higher flavor concentration, a more elastic dough and a longer shelf life of the product (Siepmann et al, 2018).

De Vuyst et al. (2007) support the fact that the synergy between lactic acid bacteria and baker's yeast gives sourdough a more intense flavor, and other researchers, as Gerez C.L. et al. (2009) and Loponen J. et al. (2009), investigate forwards the action of lactic acid bacteria on the sourdough. According to some studies, Nionelli L. and Rizzello C.G. (2016) and Jonkuviene D. et al. (2016) support the fact that different species of lactic acid bacteria determine certain specific characteristics in bread, such as: some produce flavor, others are responsible for the production of antimicrobial compounds that prolong the aging time of bread during its storage. Moreover, lactic acid bacteria produce exopolysaccharides that cause an increase in bread volume, but also a decrease in firmness (Arendt E.K., Moroni A., Zannini E., 2011).

When we talk about dough, we can say that it has one of the ancient methods of grain fermentation (Chavan, R.S. and Chavan S.R., 2011). Getting a sourdough is within everyone's reach, as it requires a few steps: grind the grains, pseudo-grains or legumes and add the water. After that, spontaneous fermentation of the lactic bacteria present in the flour will take place. All these stages lead to the formation of the sourdough (Hammes, W.P. and Gänzle, M.G., 1998).

The dynamics and result of the dough fermentation processes (backslopped) are determined both by the flour, taking into account: its type, its quality state, etc., and by the process parameters, aiming at the fermentation temperature, pH evolution, dough yield, water activity and duration of fermentation.

Symbiotic colonies of lactic acid bacteria and yeasts present in our diverse ecosystem induce lactic acid fermentation of the dough, which eventually becomes a stable culture within a few hours (De Vuyst, L. et al., 2014).

Researchers such as Raimondi et al. (2017) performed a study in which the loss of competitiveness of a stable microbial community was described only after the addition of *S. cerevisiae.*

The variability of the number and type of microbiota in the dough depends on the native microbial flora of the environment, but also on other factors such as the choice of flour type, the time and frequency of starter's feeding, the hydration level, the leavening temperature and the fermentation time of the dough (Garofalo, C. et al., 2008; Lhomme, E. et al., 2014; Gobbetti, M. et al., 1994).

Microbial cultures give the product a unique flavor profile, thanks to a group of bacteria, such as lactic acid bacteria, that produces a similar flavor of yogurt. Apart from these, sourdough can also be fermented by acetic bacteria, which produce a similar flavor of vinegar (https://truesourdough.com/18-ways-to-make-sourdough-bread-more-or-less-sour/, accessed March 12, 2023), allowing the improvement of unsatisfactory sensory qualities, especially the aroma and taste of some gluten-free bakery products (Gobbetti et al., 2014; Moroni et al., 2009).

Due to the high temperature used during baking, products can significantly lose viable bacteria and thus become a significant challenge (Zhang et al., 2018).

Microorganisms in sourdough can affect the ecosystem and functions of the starter and by default the quality of the final product (Calvert et al., 2021).

Apart from the fact that the sourdough presents a significant potential for improving the organoleptic characteristics and nutritional quality of bakery products (especially bread), its uses have also extended to other food products, such as: biscuits, waffles, pancakes,

tortillas, muffins and noodles (Poutanen et al., 2009). Üçok and Sert (2020), studied the growth kinetics of a lactic acid bacteria species, namely *Lactobacillus plantarum* L14, naturally existing in sourdough to determine its biotechnological performance and the role of the effect on the fermentation process during dough preparation. Acidity, cell count and dough properties were analyzed. With the increase in acidity during fermentation, a coagulated and stickier dough was detected.

Belkova et al. (2021) provided comprehensive information in a study on the relationship between dough composition and the formation of processing contaminants in toast bread made from yeast wheat flour. The roasting process remarkably increased the formation of acrylamide. However, sulfur-containing compounds almost tripled the formation of acrylamide during roasting.

The year 2020 has had by far a significant impact on the trend of consumers to make sourdough bread at home, as millions of people have been restricted from leaving their homes during the Covid-19 pandemic, which has led sourdough bread to the third place in the globally top of recipes searched on the Google platform (https://trends.google.com/trends/yis/2020/GLOBAL/, accessed March 12, 2023).

One of the oldest methods of obtaining a dough turned out to be through the spontaneous fermentation of the sourdough. The technique consists in fermenting the sourdough to produce a gasier dough and, as such, an airier bread. Later, brewer's yeast was added to the sourdough fermentation (Decock and Cappelle, 2005; Spicher and Stephan, 1993), which appears to have been very successful.

Considering the technological configuration, it is possible to distinguish three methods, classified into sourdough types I, II and III.

Type I sourdough refers to traditionally made dough that requires backslopping by refreshing and adding fresh flour and water at regular intervals of time (Müller, M. et al., 2001) and the fermentation of yeasts and lactic bacteria present in the flour occurs spontaneously. The second type of sourdough is obtained by inoculating industrially adapted microbial cultures to acidify it. Type III sourdough is usually a dry form of type II, easy to store and use (De Vuyst, L.; 2017; Decock, P.; 2005; Meroth, C.B. et al., 2003). The sourdough obtaining methods, classified into sourdough types I, II and III can be observed below in the Figure 1.

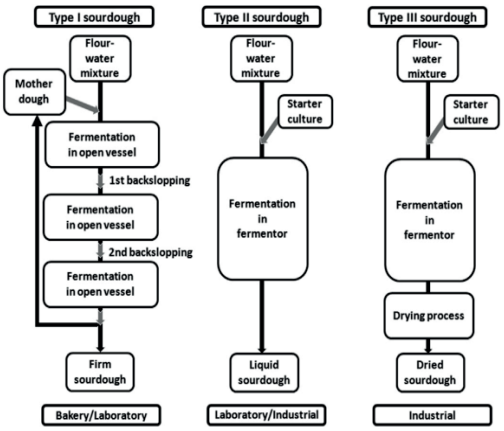

Figure 1. Types of sourdough fermentation processes according to the process technology applied (Source: https://doi.org/10.1016/bs.aambs.2017.02.003)

At the same time, some researchers considered the additional existence of another type of dough, called type 0 dough, used in the bakery industry as pre-dough or sponge dough, with the addition of baker's yeast (*Saccharomyces cerevisiae*) (De Vuyst, 2017) (Figure 2).

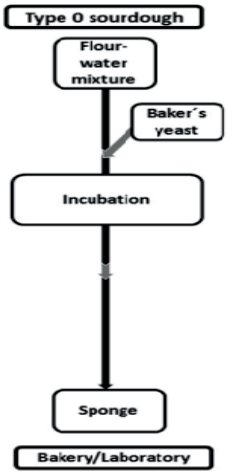

Figure 2. Type 0 dough, used in the bakery industry as pre-dough or sponge dough, with the addition of baker's yeast (Source: https://doi.org/10.1016/bs.aambs.2017.02.003)

Manufacturers in the bakery industry frequently develop type II and III dough, assuring the consumer of the quality of the product offered (Arena, M.P. et al., 2019). Type III dough brings bread an extension of the shelf life by inhibiting spoilage bacteria. Type I dough is one of the most commonly studied dough types due to its natural microbiome diversity (Plessas, 2021).

The high technology bakery industry has almost completely replaced small artisanal bakeries. Such as more efficient production technology was developed for both bread and bakery products. There has been a growing trend in demand for more flavorful bread. Thus, new businesses specialized in the production of bakery products with stabilized dough were born.

The dough fermentation produces a unique blend of flavors while improving the volume and texture of the bread. Apart from finally obtaining a product with special dough physical properties, fermentation brings bread an increased supply of nutrients, but also the extension of the shelf life (Park, D. M. et al., 2019; Katina, K. et al., 2005). The research trend is still directed towards obtaining a dough starter superior to that obtained from baker's yeast (Nionelli et al., 2018).

According to the research done by Park, D. M. et al., (2019), *Lactobacillus plantarum* SPC-SNU 72-2 proved net superior qualities in the sourdough fermentation process and was considered as a strain suitable for use in the bakery industry to obtain a bread with a slightly acidic taste.

Valerio et al. (2016) studied a fermentation product, *Lactobacillus plantarum* Bio21B. It was applied in the bread making process as a taste enhancer to obtain a yeast-leavened bread with reduced salt content (20% and 50%), compared to a reference bread (REF) that does not contain the fermentation product. Sensory analysis indicated that Bio21B bread with 50% reduced salt had a pleasant taste similar to bread containing salt (REF).

Zhou et al. (2017) had an incertitude regarding of the potential of several non-conventional yeasts and studied them as leavening agents and flavor producers under dough-like conditions in the presence of high sugar concentrations and stressful environments mimicking conditions found in the sourdough made from flour.

Hardness is an important parameter that affects the sensory quality of the bread and is a main indicator of staling during storage (Luo et al., 2018). Sensory evaluation is an important indicator, which mainly uses human senses such as: sight, smell and taste to evaluate the sensory characteristics of food, to understand people's preferences for products (Zhang, 2021).

Some researchers have come to the conclusion that the use of sourdough in the bread manufacturing process increases the feeling of satiety at the time of consumption (Zamaratskaia G., 2017). Moreover, the products obtained from cereals fermented with sourdough have a higher digestibility, compared to those fermented with yeast (Polese et al., 2018; Rizzello et al., 2019).

The composition and stability of yeast microbiota are at the basis of its applications (Table 1).

Table 1. Possible applications of sourdough lactic bacteria in bread preparation
(Source: https://doi.org/10.3390/ foods11030452)

Sourdough LAB Strains	Possible Applications
Pediococcus acidilactici LUHS29	For barley sourdough fermentation and the preparation of higher-value bread (Bartkiene, E, Vizbickiene, D. et al., 2017)
Combinations of LAB strains: *Pediococcus pentosaceus* LUHS183 and *Leuconostoc mesenteroides* LUHS242, *P. pentosaceus* LUHS183 and *Lactobacillus brevis* LUHS173, *P. pentosaceus* LUHS183 and *Enterococcus pseudoavium* LUHS234, *P. pentosaceus* LUHS183 and *Lactobacillus curvatus* LUHS51, *Lactobacillus plantarum* LUHS135 and *L. curvatus* LUHS51, *L. plantarum* LUHS135 and *P. pentosaceus* LUHS183	For wheat bread quality improving (higher porosity, better sensory properties, lower acrylamide concentration) (Bartkiene, E., Bartkevics, V. et al., 2017)
Lactobacillus coryniformis LUHS71, *L. curvatus* LUHS51, *L. farraginis* LUHS206, *Leuconostoc mesenteroides* LUHS225	For wheat bread quality improving (higher porosity, better sensory properties, lower acrylamide concentration); For surface treatment of bread to prolong the shelf life (Bartkiene, E. et al., 2019)
Pediococcus pentosaceus LUHS183, *P. acidilactici* LUHS29, *Lactobacillus paracasei* LUHS244, *Lactobacillus brevis* LUHS173, *Lactobacillus plantarum* LUHS135, *Leuconostoc mesenteroides* LUHS242	As antifungal agents against *Aspergillus nidulans*, *Penicillium funiculosum* and *Fusarium poae*; For bread safety improving (lower acrylamide concentration) (Bartkiene, E., Bartkevics, V.; Lele, V. et al., 2018)

Table 1. Possible applications of sourdough lactic bacteria in bread preparation (continuation) (Source: https://doi.org/10.3390/ foods11030452)

Sourdough LAB Strains	Possible Applications
Lactobacillus plantarum LUHS135 in combination with savory plants *Thymus vulgaris*, *Carum carvi*, *Origanum vulgare*, *Ocimum basilicum* and *Coriandrum sativum*	For bread safety improving (lower acrylamide concentration) (Bartkiene, E.; Bartkevics, V.; Krungleviciute, V. et al., 2018)
Lacticaseibacillus casei LUHS210	For almond, coconut and oat drinks by-products valorisation and added-value bread preparation (Bartkiene, E. et al., 2021)
Lactobacillus paracasei LUHS244	For okara (soybean residue) valorisation and added-value bread preparation (Juodeikiene, G. et al., 2021)

Different types of dough are known for both artisanal and industrial applications. The variety of bakery products is determined by the diversity of products obtained from sourdough.
In Europe, the use of sourdough in bakery products is quite widespread (30-50%), whereas in North America, the sourdough has less applicability. Small or medium-sized, specialized bakeries still use traditional sourdough as a leavening agent in the production of regional specialties such as: Panettone, Pumpernickel or San Francisco Sourdough Bread.
To obtain sourdough fermentation at an industrial level, semi-automatic (discontinuous) batches are carried out according to traditional fermentation procedures, incompatible with large-scale, continuous bread production (Böcker G., 2006). Therefore, sourdough fermentation is carried out by specialized suppliers in the bakery industry (Brandt M.J., 2007).
In contrast to the starter cultures used in meat and dairy fermentation, the freeze-dried ones fail to develop the metabolic activity necessary in the sourdough production process and thus require revitalization before use. When obtaining leaven, bakeries most often use stabilized, dry preparations that last a long time. They allow the new products obtained to suit the individual needs of the consumers. These preparations include ready-to-use active sourdough, dry sourdough products with added exopolysaccharides or flavor compounds derived from the Maillard reaction, and starter cultures selected to improve bread quality.
Industrial production of active dry sourdough can also be done with other types of bacteria. Bifidobacteria (Sanz-Penella J.M. et al., 2012), propionibacteria (Kariluoto S. et al., 2010), fungi and acetic acid bacteria (Haruta S. et al., 2006) grow in cereal substrates and have been used in experimental fermentations of cereals. Traditional fermentations of grains used in Africa, Asia and Latin America for the production of bread, beverages, vinegar or spices are carried out with fermentation bacteria adapted to grain substrates. The metabolic potential of these organisms differs greatly from lactic acid bacteria in yeast, and their use enables new functions for bakery products.

CONCLUSIONS

The sourdough can be obtained by three methods, classified into dough types I, II and III.
Type I dough is studied for its natural microbiome diversity, while in the bakery industry is developed frequently the type II and III dough.
Traditional sourdough is rich in microorganisms, and their composition have a great influence on the fermentation characteristics of the dough and on the appearance, taste and texture of the finished product. Lactic acid bacteria contribute to improving the dough rheology, increasing the volume and softening the texture of traditional fresh bread due to the action of the yeast to transform the soluble sugars in the dough into CO_2, alcohols, aldehydes and other substances. Lactic acid bacteria play a role in dough acidification, inhibit harmful microorganisms and react with yeast fermentation products to form aromatic substances.

ACKNOWLEDGEMENTS

This paper was published under the frame of PhD USAMVB fellowship grant and the Nucleu Programme (PN 23 01), with the support of the Romanian Ministry of Research, Innovation and Digitalization, project number PN 23 01 02 02.

REFERENCES

Arena, M.P., Russo, P., Spano, G., Capozzi, V. (2019) Exploration of the Microbial Biodiversity Associated with North Apulian Sourdoughs and the Effect of the Increasing Number of Inoculated Lactic Acid Bacteria Strains on the Biocontrol against Fungal Spoilage. *Fermentation.* 5(4):97. https://doi.org/10.3390/fermentation5040097

Arendt, E.K., Moroni, A., Zannini, E. (2011). Medical nutrition therapy: use of sourdough lactic acid bacteria as a cell factory for delivering functional biomolecules and food ingredients in gluten free bread. *Microbial Cell Factories 2011, 10 (Suppl 1): S15*. https://doi.org/10.1186/1475-2859-10-S1-S15

Aysha Tai - 18 Ways to Make Sourdough Bread More (or Less) Sour-True Sourdough-Sourdough Baking at Home. Available online: https://truesourdough.com/18-ways-to-make-sourdough-bread-more-or-less-sour/ (accessed on 12 March 2023).

Bartkiene, E.; Bartkevics, V.; Krungleviciute, V.; Pugajeva, I.; Zadeike, D.; Juodeikiene, G. (2017). Lactic acid bacteria combinations for wheat sourdough preparation and their influence on wheat bread quality and acrylamide formation. *Journal of Food and Science*. 82, 2371–2378.

Bartkiene, E.; Bartkevics, V.; Krungleviciute, V.; Pugajeva, I.; Zadeike, D.; Juodeikiene, G.; Cizeikiene, D. (2018). The influence of scalded flour, fermentation, and plants belonging to Lamiaceae family on the wheat bread quality and acrylamide content. *Journal of Food and Science*. 83, 1560–1568.

Bartkiene, E.; Bartkevics, V.; Lele, V.; Pugajeva, I.; Zavistanaviciute, P.; Mickiene, R.; Zadeike, D.; Juodeikiene, G. (2018). A concept of mould spoilage prevention and acrylamide reduction in wheat bread: Application of lactobacilli in combination with a cranberry coating. *Food Control*. 91, 284–293.

Bartkiene, E.; Bartkevics, V.; Lele, V.; Pugajeva, I.; Zavistanaviciute, P.; Zadeike, D.; Juodeikiene, G. (2019). Application of antifungal lactobacilli in combination with coatings based on apple processing by-products as a bio-preservative in wheat bread production. *Journal of Food Science and Technology*. 56, 2989–3000.

Bartkiene, E.; Bartkevics, V.; Pugajeva, I.; Borisova, A.; Zokaityte, E.; Lele, V.; Starkute, V.; Zavistanaviciute, P.; Klupsaite, D.; Zadeike, D.; et al. (2021). The quality of wheat bread with ultrasonicated and fermented by-products from plant drinks production. *Frontiers in Microbiology* 12, 586.

Bartkiene, E.; Vizbickiene, D.; Bartkevics, V.; Pugajeva, I.; Krungleviciute, V.; Zadeike, D.; Zavistanaviciute, P.; Juodeikiene, G. (2017). Application of pediococcus acidilactici LUHS29 immobilized in apple pomace matrix for high value wheat-barley sourdough bread. *LWT-Food Science and Technology*. 83, 157–164.

Bartkiene, E.; Özogul, F.; Rocha, J.M. (2022). Bread Sourdough Lactic Acid Bacteria-Technological, Antimicrobial, Toxin-Degrading, Immune System-, and Faecal Microbiota-Modelling Biological Agents for the Preparation of Food, Nutraceuticals and Feed. *Foods*, 11, 452. https://doi.org/10.3390/foods11030452

Belkova, B., Chytilova, L., Kocourek, V., Slukova, M., Mastovska, K., Kyselkac, J., Hajslova, J. (2021). Influence of dough composition on the formation of processing contaminants in yeast-leavened wheat toasted bread. *Food Chemistry*. Vol. 338. 127715. https://doi.org/10.1016/j.foodchem.2020.127715

Brandt, M.J. (2007) Sourdough products for convenient use in baking. Food Microbiology. Vol. 24, Issue 2, Pag. 161-164, https://doi.org/10.1016/j.fm.2006.07.010

Brandt, M. J. (2019). Industrial production of sourdoughs for the baking branch – An overview. *International Journal of Food Microbiology.* Volume 302, Pag. 3-7. https://doi.org/10.1016/j.ijfoodmicro.2018.09.008

Böcker, G. (2006) Principles of plants for sourdough. In: Brandt M.J., Gänzle M.G. (eds.) Sourdough Manual, 6th edition, Behr's Verlag, Hamburg, pag. 329–352

Calvert, M.D., Madden, A.A., Nichols, L.M., Haddad, N.M., Lahne, J., Dunn, R.R., McKenney, E.A., (2021). A review of sourdough starters: ecology, practices, and sensory quality with applications for baking and recommendations for future research. *PeerJ 9: e11389*. https://doi.org/10.7717/peerj.11389

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) https://doi.org/10.1111/j.1541-4337.2011.00148.x

Decock, P., & Cappelle, S. (2005). Bread technology and sourdough technology. *Trends in Food Science & Technology.* Volume 16, Issues 1–3, Pag. 113-120. https://doi.org/10.1016/j.tifs.2004.04.012

De Vuyst, L., Vancanneyt M., (2007). Biodiversity and identification of sourdough lactic acid bacteria. *Food Microbiology*. Volume 24. Issue 2. Pag. 120-127. https://doi.org/10.1016/j.fm.2006.07.005.

De Vuyst, L., Van Kerrebroeck, S., Harth, H., Huys G., Daniel, H.-M., Weckx, S. (2014). Microbial ecology of sourdough fermentations: Diverse or uniform? *Food Microbiology*. Vol. 37, Pag. 11-29, ISSN 0740-0020, https://doi.org/10.1016/j.fm.2013.06.002.

De Vuyst, L., Van Kerrebroeck, S., Leroy, F. (2017). Chapter Two - Microbial Ecology and Process Technology of Sourdough Fermentation. *Advances in Applied Microbiology.* Volume 100, Pag. 49-160. https://doi.org/10.1016/bs.aambs.2017.02.003

Garofalo, C., Silvestri, G., Aquilanti, L., Clementi, F. (2008). PCR-DGGE analysis of lactic acid bacteria and yeast dynamics during the production processes of three varieties of Panettone. *Journal of Applied Microbiology.* 105(1):243-54. https://doi.org/10.1111/j.1365-2672.2008.03768. PMID: 18312562.

Gerez, C.L., Torino, M.I., Rollán, G., Font de Valdez G. (2009). Prevention of bread mould spoilage by using lactic acid bacteria with antifungal properties. *Food Control*. 20. 144-148. https://doi.org/10.1016/j.foodcont.2008.03.005

Gobbetti, M., Corsetti, A., Rossi, J., La Rosa, F., De Vincenzi, S. (1994). Identification and clustering of lactic acid bacteria and yeasts from wheat sourdoughs of Central Italy. *Italian Journal of Food science*. 6(1):85-94. ISSN: 1120-1770

Gobbetti, M., Rizzello, C.G., Di Cagno, R., De Angelis, M. (2014). How the sourdough may affect the functional features of leavened baked goods. *Food Microbiology.* 37:30-40. https://doi.org/10.1016/j.fm.2013.04.012. PMID: 24230470

Google's Year in Search-Google Trends. Available online: https://trends.google.com/trends/yis/2020/GLOBAL/ (accessed on 12 March 2023).

Haruta S., Ueno S., Egawa I., Hashiguchi K., Fujii A., Nagano M., Ishii M., Igarashi Y. (2006) Succession of bacterial and fungal communities during a traditional pot fermentation of rice vinegar assessed by PCR-mediated denaturing gradient gel electrophoresis. International Journal of Food Microbiology. Volume 109, Issues 1–2, Pag. 79-87. https://doi.org/10.1016/j.ijfoodmicro.2006.01.015

Hammes, W.P., Gänzle, M.G. (1998). Sourdough breads and related products. In: Wood, B.J.B. (eds) *Microbiology of Fermented Foods.* Springer, Boston, MA. https://doi.org/10.1007/978-1-4613-0309-1_8

Jonkuviene, D., Vaiciulyte-Funk, L., Salomskiene, J., Alencikiene, G., Miezeliene, A. (2016). Potential of Lactobacillus reuteri from spontaneous sourdough as a starter additive for improving quality parameters of bread. *Food Technology & Biotechnology.* 54 (3): 342–350. https://doi.org/10.17113/ftb.54.03.16.4143

Juodeikiene, G.; Trakselyte-Rupsiene, K.; Navickaite, B.; Zadeike, D.; Bendoraitiene, J.; Bartkiene, E.; Lele, V.; Rueller, L.; Robert, J.; Arnoldi, A.; et al. (2021). Functionalization of soya press cake (okara) by ultrasonication for enhancement of submerged fermentation with Lactobacillus paracasei LUHS244 for wheat bread production. *LWT*. 152, 112337.

Kariluoto S., Edelmann M., Herranen M., Lampi A.M., Shmelev A., Salovaara H., Korhola M., Piironen V. (2010) Production of folate by bacteria isolated from oat bran. International Journal of Food Microbiology. Volume 143, Issues 1–2, Pag. 41-47. https://doi.org/10.1016/j.ijfoodmicro.2010.07.026

Katina, K., Arendt, E., Liukkonen, K.H., Autio, K., Flander, L., Poutanen, K. (2005). Potential of sourdough for healthier cereal products. *Trends in Food Science & Technology.* Vol. 16, Issues 1–3, Pag. 104-112. https://doi.org/10.1016/j.tifs.2004.03.008

Kumar, R., & Dhanda, S. (2017). Mechanistic insight of probiotics derived anticancer pharmaceuticals: a road forward for cancer therapeutics. *Nutrition and Cancer.* 69:3. Pag. 375-380. https://doi.org/10.1080/01635581.2017.1267773

Lhomme, E., Urien, C., Legrand, J., Dousset, X., Onno, B., Sicard, D. (2014) Sourdough microbial community dynamics: An analysis during French organic bread-making processes. *Food Microbiology*. 53. https://doi.org/10.1016/j.fm.2014.11.014

Loponen, J., Kanerva, P., Zhang, C., Sontag-Strohm, T., Salovaara, H., & Gänzle, M. G. (2009). Prolamin Hydrolysis and Pentosan Solubilization in Germinated-Rye Sourdoughs Determined by Chromatographic and Immunological Methods. *Journal of Agricultural and Food Chemistry*. 57(2), 746–753. https://doi.org/10.1021/jf803243w

Luo, D., Wu, R., Zhang, J., Zhang, K., Xu, B., Li, P., Yuan, Y., Li, X. (2018). Effects of ultrasound assisted dough fermentation on the quality of steamed bread. *Journal of Cereal Science.* Vol. 83. Pag. 147-152. https://doi.org/10.1016/j.jcs.2018.07.016

Meroth, C.B., Walter, J., Hertel, C., Brandt, M.J., Hammes, W.P. (2003). Monitoring the bacterial population dynamics in sourdough fermentation processes by using PCR-denaturing gradient gel electrophoresis. *Applied and Environmental Microbiology.* Vol. 69(1), 475-82. https://doi.org/10.1128/AEM.69.1.475-482.2003. PMID: 12514030; PMCID: PMC152404

Montemurro, M., Pontonio, E., Gobbetti, M., Rizzello, C.G. (2019). Investigation of the nutritional, functional and technological effects of the sourdough fermentation of sprouted flours. *International Journal of Food Microbiology.* 302:47-58. https://doi.org/10.1016/j.ijfoodmicro.2018.08.005. PMID: 30115372.

Moroni, A.V., Dal Bello, F., Arendt, E.K. (2009). Sourdough in gluten-free bread-making: an ancient technology to solve a novel issue? *Food Microbiology*. 26(7):676-84. https://doi.org/10.1016/j.fm.2009.07.001. PMID: 19747600.

Müller, M., Wolfrum, G., Stolz, P., Ehrmann, M.A., Vogel, R.F. (2001). Monitoring the growth of Lactobacillus species during a rye flour fermentation. *Food Microbiology* 18. 217-227. https://doi.org/10.1006/FMIC.2000.0394

Nazir, Y., Hussain, S.A., Hamid, A.A., Song, Y. (2018). Probiotics and their potential preventive and therapeutic role for cancer, high serum cholesterol, and allergic and HIV diseases. *BioMed Research International.* 2018: 3428437. https://doi: 10.1155/2018/3428437. PMID: 30246019. PMCID: PMC6136537.

Nionelli, L., & Rizzello, C.G. (2016). Sourdough-based biotechnologies for the production of gluten-free foods. *Foods*, 5(3): 65. https://doi.org/10.3390/foods5030065

Nionelli, L., Montemurro, M., Pontonio, E., Verni, M., Gobbetti, M., Rizzello, C.G. (2018). Pro-technological and functional characterization of lactic acid bacteria to be used as starters for hemp (Cannabis sativa L.) sourdough fermentation and wheat bread fortification. *International Journal of Food Microbiology.* Volume 279, Pag. 14-25. https://doi.org/10.1016/j.ijfoodmicro.2018.04.036

Park, D. M., Bae, J.-H., Kim, M. S., Kim, H., Kang, S. D., Shim, S., Lee, D., Seo, J.-H., Kang, H., Han, N. S. (2019). Suitability of Lactobacillus plantarum SPC-SNU 72-2 as a Probiotic Starter for Sourdough Fermentation. *Journal of Microbiology and Biotechnology.* https://doi.org/10.4014/jmb.1907.07039

Plessas, S. (2021). Innovations in Sourdough Bread Making. *Fermentation.* 7(1):29. https://doi.org/10.3390/fermentation7010029

Polese, B., Nicolai, E., Genovese, D., Verlezza, V., La Sala, C. N., Aiello, M., Inglese, M., Incoronato, M., Sarnelli, G., De Rosa, T., Schiatti, A., Mondelli, F., Ercolini, D., Cuomo, R., (2018) Postprandial Gastrointestinal Function Differs after Acute Administration of Sourdough Compared with Brewer's Yeast Bakery Products in Healthy Adults, *The Journal of Nutrition*, Vol. 148. Issue 2. Pag. 202–208. https://doi.org/10.1093/jn/nxx049

Poutanen, K., Flander, L., Katina, K. (2009). Sourdough and cereal fermentation in a nutritional perspective. *Food Microbiology.* Vol. 26. Issue 7. Pag. 693-699. ISSN 0740-0020. https://doi.org/10.1016/j.fm.2009.07.011

Raimondi, S., Amaretti, A., Ross,i M., Fall, P.A., Tabanelli, G., Gardini, F., Montanari, C., (2017). Evolution of microbial community and chemical properties of a sourdough during the production of Colomba, an Italian sweet leavened baked product. *LWT - Food Science and Technology*. Vol. 86, Pag. 31-39. http://dx.doi.org/10.1016/j.lwt.2017.07.042

Rizzello, C.G., Portincasa, P., Montemurro, M., Di Palo, D.M., Lorusso, M.P., De Angelis, M., Bonfrate, L., Genot, B., Gobbetti, M. (2019). Sourdough Fermented Breads are More Digestible than Those Started with Baker's Yeast Alone: An In Vivo Challenge Dissecting Distinct Gastrointestinal Responses. *Nutrients*. Vol. 11(12). Pag. 2954. https://doi.org/10.3390/nu11122954

Sanz-Penella J.M., Laparra J.M., Sanz Y., Haros M. (2012) Assessment of iron bioavailability in whole wheat bread by addition of phytase-producing bifidobacteria. Journal of Agricultural and Food Chemistry. 60(12):3190-5. https://doi.org/10.1021/jf205048r

Siepmann, F.B., Ripari, V., Waszczynskyj, N., Spier, M. R. (2018). Overview of Sourdough Technology: from Production to Marketing. *Food and Bioprocess Technology, 11*, 242–270. https://doi.org/10.1007/s11947-017-1968-2

Spicher G., Stephan H. (1993) Handbuch Sauerteig: Biologie, Biochemie, Technologie. 4th ed. Hamburg, Germany: B. Behr's Verlag

The Technology of Sourdough Starters. Available online: https://bakerpedia.com/the-technology-of-sourdough-starters/(accessed on 12 March 2023).

Üçok, G. & Sert, D. (2020). Growth kinetics and biomass characteristics of Lactobacillus plantarum L14 isolated from sourdough: Effect of fermentation time on dough machinability. *LWT - Food Science and Technology.* Vol. 129. 109516. https://doi.org/10.1016/j.lwt.2020.109516

Valerio, F., Conte, A., Di Biase, M., Lattanzio, V.M.T., Lonigro, S.L., Padalino, L., Pontonio, E., Lavermicocca, P. (2016). Formulation of yeast-leavened bread with reduced salt content by using a Lactobacillus plantarum fermentation product. *Food Chemistry.* https://doi.org/10.1016/j.foodchem.2016.11.135

Zamaratskaia, G., Johansson, D., Junqueira, M., Deissler, L., Langton, M., Hellström, P., Landberg, R. (2017). Impact of sourdough fermentation on appetite and postprandial metabolic responses – a randomised cross-over trial with whole grain rye crispbread. *British Journal of Nutrition.* 118(9). 686-697. https://doi.org/10.1017/S000711451700263X

Zhang, L., Taal, M. A., Boom, R. M., Chen, X. D., Schutyser, M. A. I. (2018). Effect of baking conditions and storage on the viability of Lactobacillus plantarum supplemented to bread. *LWT - Food Science and Technology.* Vol. 87. Pag. 318–325. http://doi.org/10.1016/j.lwt.2017.09.005

Zhang, Z. (2021). Sensory evaluation of different drinks formulated from dendrobium officinale flowers using fuzzy logic. *Journal of food measurement & characterization.* Vol. 15(4). Pag. 3060-3068. https://doi.org/10.1007/s11694-021-00877-y

Zhou, N., Schifferdecker, A. J., Gamero, A., Compagno, C., Boekhout, T., Piškur, J., Knecht, W. (2017). Kazachstania gamospora and Wickerhamomyces subpelliculosus: Two alternative baker's yeasts in the modern bakery. *International Journal of Food Microbiology*. Vol. 250. Pag. 45–58. https://doi.org/10.1016/j.ijfoodmicro.2017.03.013