Chapter 12
Traditional Rye Sourdough Bread in the Baltic Region

Grazina Juodeikiene

12.1 Introduction

Many European supermarkets offer bread loaves from around the continent—from the French baguette through to the Italian ciabatta and Germany's dark pumpernickel. But ironically, despite the variety, many consumers are turning back to local bakeries or even rolling up their sleeves to make their own bread at home like some of their grandparents. On top of this, for home and kitchen cooking and baking equipment, one can buy easily in every electric home appliances shop. This new trend does not surprise food scientists who think that consumers are searching for the kind of flavour and texture often sacrificed during industrial bread making. Humans ate rye sourdough bread in ancient times, and it remains a traditional part of the diet in the Baltic region (Sahlstrom and Knutsen 2010). Rye sourdough is a mixture of rye flour and water and contains metabolically active lactic acid bacteria (LAB), which contribute to the bread's special flavour and taste (Rosenquist and Hansen 2000; Hammes et al. 1996; Venskaityte et al. 2005). Sourdough is used as an essential ingredient for acidification, leavening and production of flavour compounds and biopreservation of bread (Katina et al. 2005; De Vuyst and Leroy 2007; Sadeghi 2008). In addition, several researchers have reported on how sourdough bread can resist microbiological spoilage by moulds and rope-forming bacilli due to the production of inhibitory substances (Katina et al. 2002; Hassan and Bullerman 2008; Sadeghi 2008; Valerio et al. 2009). As in the other Baltic countries, Lithuanians still eat sourdough bread—a pleasant-tasting bread that uses natural leavening, which traces back to the ancient Egyptians (Imbrasiene 2008).

G. Juodeikiene (✉)
Kaunas University of Technology, K. Donelaičio g. 73, Kaunas, Lithuania
e-mail: grazina.juodeikiene@ktu.lt

K. Kristbergsson, J. Oliveira (eds.), *Traditional Foods*, Integrating Food Science and Engineering Knowledge Into the Food Chain 10,
DOI 10.1007/978-1-4899-7648-2_12

12.2 Ancient Art in Modern Bread Making

The leavening technique of modern bread making was replaced in many countries by industrially processed yeast and food additives, but sourdough bread has continued to be the main staple in the Baltics and some other regions of the world. In comparison with the rye bread processes used in the EU, the major difference in the Baltic region is the scalding step in the process which gives the product a pleasant sweet tone (Fig. 12.1).

In sourdough, the secret ingredient is a "starter" or "mother" of flour and water that ferments when a lactobacillus bacteria culture is added. That starter gives the lightness to the dough. This living culture is fed and preserved for use in successive loaves and often passed down through generations. Malted rye flour, often enzymatically non-active, is added to scald when traditional sourdough production is used in order to give the bread a dark brown colour, which Baltic consumers like. Besides, caraway seeds or sometimes linseeds are an essential part of rye bread. The seeds are mostly used whole and often they are added to the scald process. Some breads may be even decorated with caraway seeds. Traditionally, country rye bread loaves are often very big, e.g. today in Latvia one can buy a rye loaf weighing up to 5 kg. These breads are still produced with traditional methods using much hand work, and they may be baked in big stone ovens. For the up-to-date consumer's convenience, these huge loaves are available sliced and packed. The most common weight of rye bread loafs is 0.7–1.0 kg. In Lithuania, it is still common to buy an unsliced 2 kg loaf, packed in a colourful plastic bag. Traditional rye breads in the Baltic countries are oval in shape. The crust of the traditional loaf is very thick, often more than 1 cm. Due to the flour cooking and gelatinization processes, bread crumb is very moist and sometimes sticky and has a long shelf life.

Rye is rich in dietary fibre and this type of cereal is an excellent raw material for sourdough preparation as well as for a healthy and tasty bread product. In a time where people prefer a healthy diet, the option of sourdough bread making is attractive. The method is ideally suitable for making rye bread—which has lower calorie content than many other types of bread as well as containing more dietary fibre. Other particularity is that baker's yeast does not work well as a leavening agent with rye flour. The leavening action is taken over partly by LAB so that one can decrease the amount of baker's yeast.

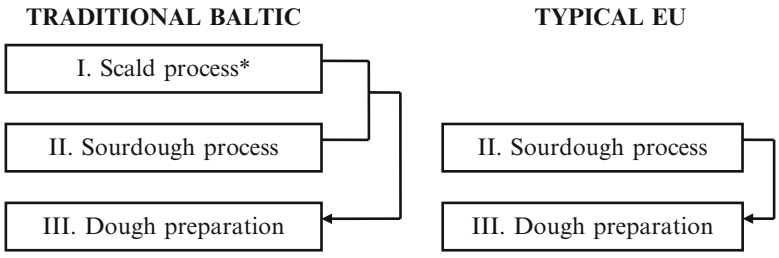

Fig. 12.1 Comparison of rye sourdough processes used in the Baltic countries and elsewhere in the EU. *The scald process is actually a heat treatment of a flour matrix with hot water or steam. This matrix is brought in a certain amount of time and by a certain temperature to gelatinization

12.3 Microbial Population of Lithuanian Spontaneous Rye Sourdoughs

12.3.1 General Aspects

LAB are an important group of industrial starter cultures, which has a long tradition in bread making. The LAB that developed in the dough may originate from selected natural occurrence in the flour or from a starter culture containing one or more known species of LAB. In Lithuania the oldest and most popular rye bread technology is with spontaneous sourdough. The organoleptic and structural properties of bread, as well as their keeping quality and the changes in the properties associated with staling, are remarkably affected by the fermentation process and the microbial ecology of the sourdough (Röcken and Voysey 1995; Rosenquist and Hansen 1998; Gänzle and Vogel 2003). High-quality sourdough bread is dependent on a consistent and microbial stable sourdough. LAB and yeast cohabit in the sourdough and interact for their carbohydrate, amino acid and vitamin requirements. During rye dough fermentation, LAB play the main role; therefore, their amount in the dough is ten times higher than those of yeast. Both homo-fermentative and hetero-fermentative LAB lower the pH by the production of lactic acid, thus allowing the swelling of pentosans and proteins in rye, improving the sensory properties and shelf life (Stolz and Böcker 1996). Moreover, hetero-fermentative LAB also contribute to the leavening and affect flavour.

The microflora responsible for sourdough fermentation in different countries has been characterised, for example, in Germany (Müller et al. 2001; Meroth et al. 2003), Finland (Salovaara and Katunpää 1984), Russia (Kazanskaya et al. 1983), Sweden (Spicher and Lönner 1985), Denmark (Rosenquist and Hansen 2000) and other countries. About 43 different sourdough species of LAB have been reported until now. The majority are members of the LAB core genera *Lactobacillus* and to a lesser extent of *Lactococcus*, *Pediococcus*, *Weissella* and *Leuconostoc*. The most frequently isolated species are *Lactobacillus sanfranciscensis*. This microorganism is effective in the fermentation of maltose and is able to hydrolyse raffinose, galactose and ribose. Therefore, sourdough with this strain is characterised by very good microbiological, biochemical and baking properties. During spontaneous fermentation, both lactobacilli (homo-fermentative *Lactobacillus plantarum*, *L. delbrueckii*, *L. farciminis*, *L. casei*, *L. acidophilus* and *L. johnsonii* and hetero-fermentative *L. brevis*, *L. fermentum*, *L. buchneri*, *L. fructivorans*, *L. pontis* and *L. panis*) and pediococci (*Pediococcus pentosaceus*, *P. acidilactici*) develop. The homo-fermentative organisms are dominating, and no significant differences exist between rye and wheat. *Leuconostoc* and *Weissella* may play a role during the first phase of fermentation, and they can be important for the growth of lactobacilli. Pediococci usually exist at the end of the fermentation process of plant material (De Vuyst and Neysens 2005).

Several factors account for the dominance of sourdough lactobacilli during traditional dough preparation. First, their carbohydrate metabolism is highly adapted to the main energy sources in dough, maltose and fructose. Utilisation of maltose via maltose phosphorylase and the pentose phosphate shunt with fructose as co-substrate

results in a higher energy yield than homo-fermentative maltose degradation. Second, the growth requirements of *L. sanfranciscensis* with respect to temperature and pH match the conditions encountered during sourdough fermentation. Similarly growth of *L. amylovorus* occurs optimally under rye sourdough fermentation conditions. Third, antimicrobial compounds may contribute to the stable persistence of lactobacilli in sourdough fermentations.

Many studies have been carried out on the lactic microflora of sourdough and the microflora may vary significantly with types, thus contributing to the peculiar characteristics of many traditional breads. Because of scarce data in literature of microbial population and of antimicrobial activity of Lithuanian sourdoughs, the traditional spontaneous rye sourdoughs have been taken in consideration (Digaitiene et al. 2005).

12.3.2 Physicochemical and Microbiological Characteristics of Sourdoughs in Lithuania

The physicochemical and microbiological characteristics of the sourdoughs in Lithuania have been studied in different sourdoughs: three rye sourdoughs (samples G, H, K) were received from different bakeries in Lithuania, and sourdoughs A to F were prepared from Lithuanian whole meal rye flour according to the most common traditional procedure used locally by changing the rates of flour and water (1:1 or 1:2), fermentation temperatures (25, 30 or 35 °C) and time (24 or 48 h). Conditions of sourdough preparations are shown in Table 12.1.

Table 12.1 shows the fermentation time (FT), pH, titratable acidity (TTA) and population of tested sourdoughs (LAB, CFU g^{-1}). In all investigated samples (a total of nine sourdoughs), the pH values ranged from 4.21 to 3.72 and the TTA from

Table 12.1 Physicochemical and microbiological characteristics of some sourdoughs in Lithuania

Sample	Fermentation temperature (°C)	FT[a] (h)	pH	TTA[b]	LAB (CFU g^{-1})	Consistence
A	30	48	4.09	20.8 ± 0.11	3.1×10^8	Thick
B	30	48	3.94	18.1 ± 0.33	3.4×10^8	Fluid
C	25	72	3.94	22.2 ± 0.23	2.8×10^8	Thick
D	25	72	3.72	19.5 ± 0.06	2.1×10^8	Fluid
E	35	72	3.90	21.9 ± 0.19	4.0×10^8	Thick
F	35	72	3.78	18.9 ± 0.09	2.0×10^8	Fluid
G	–	–	4.21	16.0 ± 0.14	4.5×10^6	Thick
H	–	–	4.05	27.9 ± 0.20	2.2×10^6	Thick
K	–	–	3.85	29.9 ± 0.10	1.2×10^6	Fluid

[a]Fermentation time

[b]Total titratable acidity—determined on 10 g of sample homogenised with 90 mL of distilled water and expressed as the amount (mL) of 0.1 M NaOH to get pH of 8.2

16.0±0.14 to 29.9±0.10. The lowest pH of 3.72 and 3.78 was determined for the sourdough samples D and F, respectively, and the highest—for sample G. The highest TTA was noticed for samples K (29.9) and H (27.9), while the lowest TTA was noticed for sample G (16). The rather high pH of 4.21 of sample G could be attributed to the dominance of low-acidifying species of LAB due to the different technology applied in sourdough preparation as well as the buffering capacity of the flour used. The total number of LAB of the samples ranged from 2.2×10^6 to 4.0×10^8 CFU g^{-1}. The highest count of LAB was observed in the sourdough sample E. These results of the number of LAB and acidity in the sourdoughs were similar to other published results on rye sourdoughs (Kazanskaya et al. 1983; Salovaara and Katunpää 1984; Spicher and Lönner 1985; Spicher and Stephan 1993; Müller et al. 2001).

12.3.3 Phenotypic Characteristics of Isolates

To obtain a first overview of the fermentation flora, a total of 56 LAB were randomly chosen for phenotypic and genotypic identification. All isolates were Gram positive, catalase is negative, and 24 strains were recognised as rods and the others as *cocci* (Table 12.2).

Based on their morphological character and carbohydrate fermentation patterns, the isolates were initially divided into six groups. Group No. 1, containing 42 % of the isolates, was rods hydrolysing sucrose, maltose, trehalose and glucose. Only one isolate (group No. 2) fermented all the five tested sugars. Group No. 3 (38 %) and No. 4 (17 %) were differentiates due to their ability to ferment trehalose. The *cocci* were divided into two groups No. 5 (69 %) and No. 6 (31 %) based on their ability to ferment sucrose and maltose. All of them could ferment trehalose and glucose. Accordingly, the rods showed greater variation than the *cocci* as they were divided into four groups.

12.3.4 Genetic Characterisation of the LAB

In order to determine to which species the isolate belonged to, representatives for each group were analysed genetically. The internally transcribed spacer PCR method was applied on isolates K6, K3, K28, H5, K4, K5, H8, H15, C5, C11, C27, D6, E4, E8 and E16. The isolates could be divided in five clusters (Fig. 12.2) based on mobility and their number of amplified ITS fragments separated after agarose gel electrophoresis. Isolates belonging to the same group gave identical band pattern of ITS fragments. Thus, group No. 1 had pattern X1, group No. 3, X3; group No. 4, *X*2; group No. 5, X4; and group No. 6, X5.

One or a few representatives from each group (No. 1, K6; No. 2, K1; No. 3, K3; No. 4, H15; No. 5, C2, C11, D12, F27; No. 6, E16, F15) were further analysed by amplification and sequencing of 16S rDNA. The identification of *Lactobacillus*

Table 12.2 Phenotypic characteristics of isolates

Group	Strain	Morphology	Carbohydrate fermentation					Growth at 50 °C
			Arabinose	Sucrose	Maltose	Trehalose	Glucose	
1	G3, G5, G11, G20, K6, K7, H9, H24, H27, H29	Rods	−	+	+	+	+	n.d.
2	K1		+	+	+	+	+	n.d.
3	K3, K9, K11, K26, K28, K29, K30, H1, H5		−	−	+	+	+	n.d.
4	K4, K5, H8, H15		−	−	+	±	+	n.d.
5	A11, A26, A27, B2, B9, B11, B27, C1, C2, C5, C11, C21, C27, D5, D6, D7, D12, D23, E10, E30, F4, F27	Cocci	−	±	+	+	+	−
6	D8, D25, E2, E4, E8, E16, E22, E27, F3, F15		−	−	−	+	+	+

"+" ferment, "−" not ferment, ± weak fermentation, n.d. not determined

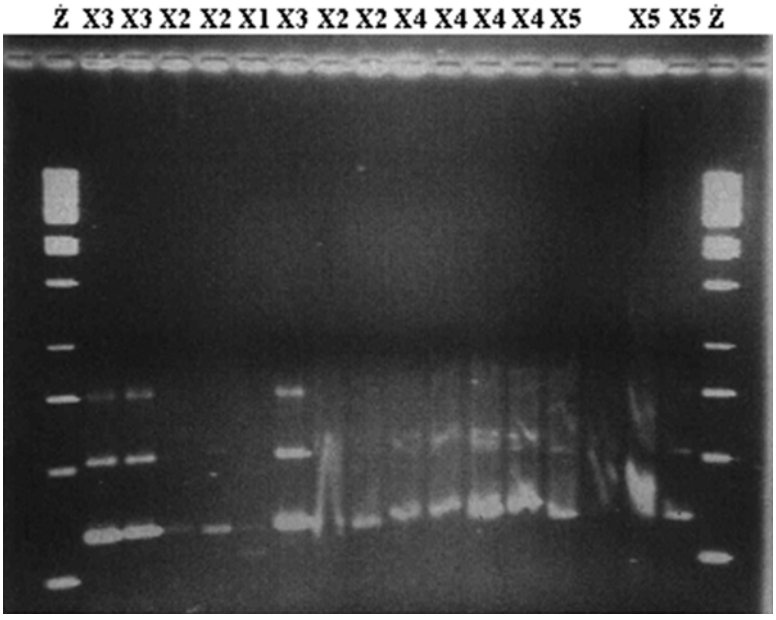

Fig. 12.2 Clustering of ITS patterns generated by PCR with 16S-1500F and 23S-32R primers. *M* marker 50 bp DNR GeneRuler, *X1* group No. 1 (K6), *X2* group No. 4 (K4, K5, H8, H15), *X3* group No. 3 (K3, K28, H5), *X4* group No. 5 (C5, C11, C27, D6) and *X5* group No. 6 (E4, E8, E16)

strains belonging to cluster X3 was not possible, because the tested strain (K3) did not generate any product after PCR amplification. The obtained sequences (Table 12.3) were compared to strains in the NCBI Blast Library (Table 12.4).

The homology search showed that strains K1 and H15 are either *L. sakei* or *L. curvatus* and K6 either *L. farciminis* or *L. paralimentarius*, while the other strains showed high similarity to both *P. pentosaceus* and *P. acidilactici.*

In order to differentiate between the two possibilities, the strains were grown at different temperatures and on selected carbon sources. *L. sakei* differs from *L. curvatus* in the fermentation of arabinose, sucrose, maltose and trehalose. It was determined that the strain K1 was able to ferment these sugars and so it was designated as belonging to *L. sakei*. The LAB H15 fermented trehalose very weakly and did not ferment arabinose and sucrose, showing that it belongs to *L. curvatus. L. farciminis* and *L. paralimentarius* differ in the fermentation of maltose; LAB K6 fermented maltose very well so it belongs to *L. farciminis*.

P. pentosaceus differs from *P. acidilactici* in the fermentation of maltose and growth at 50 °C. As isolates C2, C11, D12 and F27 fermented maltose and did not grow at 50 °C, they identify themselves as isolates belonging to *P. pentosaceus.* Strains E16 and F15 did not ferment maltose but was grown at 50 °C showing that they belong to *P. acidilactici*.

Table 12.3 Species identification based on 16S rDNA gene sequence comparison

LAB strain	16S rDNR gene sequence
K6	GGTGGCTTCCCCCCTGCTTCCCCGGGTCTNCTGCGTGCGAGCCTCTTTCGCTCGATCTGNG
	AAGTNTTGTTTGCGGTTTGCCCTGTTTCCGATGTTATCCCCCNCTTTTGGGCCGGTTACCCA
	CGTGTTACTCACCCGTCCGCCACTCACCANGGTCTGAATCNTGAAGCGAGCTTCNTTCTTC
	NGGATGGTTCGTTCGTACTTGCNNTGTATTAGTGCATGCCGCCAGACGTTCGTCCTGAGCC
	ATGATC
K1	GGGTCCTCCTAAAGTGATAGCCGAAACCATCTTTCAACCCTACACCATGCGGTGTTAGGTT
	TTATGCGGTATTAGCATCTGTTTCCANNATGTTATCCCCCACTTTAGGGCAGGTTACCCACG
	TGTTACTCACCCGTCCGCCACTCACTCAAATGTTTATCAATCAGGAGCAAGCTCCTTCAAT
	CTAAACGAGAGTGCGTTCGACTTGCATGTAT
H15	CGCCTGCTGCCGTNGGTGGCNTNNCCCCNCTNCTGTGCCCGCGGGTCCTCCTNGTGTGCCG
	NCCTCTTTCTCCCTCCCTGCGGTGTTGGTTTTTGCGGTTTGCTCTGTTTCCATGTTTCCCCCC
	TTTGGGCGGTTACCCCGTGTTACTCCCCGTCCGCCCTCCTCNAATGTNTATCATCNGGAGC
	AAGCTCCTTCAATCTAAACGAGAGTGCGTNCCGACTTGCATGTATTAGGCACGCCGCCNG
	CGTTCGTCCTGAGCC
C2	GGTCCATCCAGAAGTGATAGCAGAGCCATCTTTTAAAAGAAAACCATGCGGTTTTCTCTGT
	TATACGGTATTAGCATCTGTTTCCAGGTGTTATCCCCTACTTCTGGGCAGGTTACCCACGTG
	TTACTCACCCGTTCGCCACTCACTTCGTGTTAAAATCTCAATCAGTACAAGTACGTCATAAT
	CAATTAACGGAAGTTCGTTCGACTTGCATGTATTAGGCACGCCGCCAGCG
C11	AGTCCTTCCGTGGAGGGNCGCTANCNCCNCCAACTACTAATCNCCGCGGGGTCNTNCGAA
	AANTGNATAGCAGAGCCATCTTTTAAAAGAAAACCATGCGGTTTTCTCTGTTATACGGTAT
	TAGCATCTGTTTCCAGGNGTTATCCCCTACTTCTGGGCAGGTTACCCACGTGTTACTCACCC
	GTTCGCCACTCACTTCGTGTTAAAATCTCAATCAGTACAAGTACGTCATAATCAATTAACG
	GAAGTTCGTTCGACTTGGCATGTATNAGGGCACGCCGCCAGCGTTCATCCT
D12	TCGGCTACGTATCACTGCCTTGGTGAGCCTTTACCTCACCAACTAGCTAATACGCCGCGGG
	TCCATCCAGAAGTGATAGCAGAGCCATCTTTCAAAAGAAAACCATGCGGTTTTCTCTGTTA
	TACGGTATTAGCATCTGTTTCCAGGTGTTATCCCCTACTTCTGGGCAGGTTACCCACGTGTT
	ACTCACCCGTTCGCCACTCACTTCGTGTTAAAATCTCAATCAGTACAAGTACGTCATAATC
	AATTAACGGAAGTNCGTTCGACTTGCATGTATTAGGCACGCCGCCAGCGTTCAT
F27	CGCCTTGAGTGAGCCGTTACCTCACCAACTAGCTAATGCGCCGCGGGTCCATCCAGAAGTG
	ATAGCAGAGCCATCTTTTAAAAGAAAACCAGGCGGTTTTCTCTGTTATACGGTATTAGCAT
	CTGTTTCCAGGTGTTATCCCCTGCTTCTGGGCAGGTTACCCACGTGTTACTCACCCGTCCGC
	CACTCACTTCGTGTTAAAATCTCATTCAGTGCAAGCACCTCATNGATCAATTAACGGAAGT
	TC
E16	CCGATTACCCTCTCATGTCGGCTACGTATCACTGCCTTGGTGAGCCTTTACCTCACCAACTA
	GCTAATACGCCGCGGGTCCATCCAGAAGTGATAGCAGAGCCATCTTTTAAAAGAAAACCA
	TGCGGTTTTCTCTGTTATACGGTATTAGCATCTGTTTCCAGGTGTTATCCCCTACTTCTGGG
	CAGGTTACCCACGTGTTACTCACCCGTTCGCCACTCACTTCGTGTTAAAATCTCAATCAGTA
	CAAGTACGTCATAATCAATTAACGGAAGTTCGTTCGACTTGCATGTATTAGGCACGCCGCC
	AGCGTTCATCCTGAGCCATGA
F15	GTCGGCTACGCATCATCGCCTTGGTGAGCCGTTACCTCACCAACTAGCTAATGCGCCGCGG
	GTCCATCCAGAAGTGATAGCAGAGCCATCTTTTAAAAGAAAACCAGGCGGTTTTCTCTGTT
	ATACGGTATTAGCATCTGTTTCCAGGTGTTATCCCCTGCTTCTGGGCAGGTTACCCACGTGT
	TACTCACCCGTCCGCCACTCACTTCGTGTTAAAATCTCATTCAGTGCAAGCACGTCCTGATC
	AATTAACGGAAGTTCGTTCGACTTGCATGTATTAGGCACGCCGCCAGCGT

Table 12.4 Species identification based on 16S rDNA gene sequence comparison

Isolates	NCBI lactic acid bacteria strain	Similarity (%)	Accession number
K6	*L. farciminis* DSM2018	90	AJ417499.1
	L. paralimentarius DSM13238	88	AJ417500.1
K1	*L. sakei* HNSL5a	99	AY204896.1
	L. curvatus subsp. melibiosus CCUG 34545	99	AY204889.1
H15	*L. sakei subsp. carnosus* CCUG31331	91	AY204892.1
	L. curvatus subsp. melibiosus CCUG 34545	91	AY204889.1
C2	*P. pentosaceus* LM 2632	100	AY675245.1
	P. acidilactici RO 17	97	AF515229.1
C11	*P. pentosaceus* LM 2632	98	AY675245.1
	P. acidilactici RO 17	95	AF515229.1
D12	*P. pentosaceus* LM 2632	99	AY675245.1
	P. acidilactici RO 3	94	AY375299.1
F27	*P. pentosaceus* LM 2632	96	AY675245.1
	P. acidilactici YDW 17	100	AF375935.1
E16	*P. pentosaceus* LM 2632	99	AY675245.1
	P. acidilactici RO 17	96	AF515229.1
F15	*P. pentosaceus* LM 2632	95	AY675245.1
	P. acidilactici DSMZ 202	100	AJ249539.1

12.3.5 Genetic Characterisation of the Species

According to the species genetic characterisation, *L. farciminis* belongs to group No. 1, *L. sakei* to group No. 2, *Lactobacillus ssp*. to group No. 3, *L. curvatus* to group No. 4, *P. pentosaceus* to group No. 5 and *P. acidilactici* to group No. 6. The composition of lactic microflora of sourdoughs is shown in Table 12.5.

For each sample, the percentage of isolates (referred to the total number of isolates for a given sample) belonging to different groups is shown. The bacterial flora of the commercial sourdoughs (G, H, K) consisted of four species belonging to genus *Lactobacillus*. A high percentage of isolates identified as *L. farciminis* (from 50 % for sample H to 100 % for sample G) was found in most samples. Moreover, sample H had the same quantity (25 %) of *L. curvatus* and not identified *Lactobacillus* spp. In sample K a more heterogeneous composition of the microflora was found as it consisted of *Lactobacillus* spp. (58 %). Also *L. farciminis* (17 %), *L. curvatus* (17 %) and *L. sakei* (8 %) were isolated. In contrast to the commercial sourdoughs, the samples prepared from Lithuanian rye flour (A–F) also harbour strains belonging to predominant species of *P. pentosaceus* (from 60 % for sample F and 71 % for sample D to 100 % for sample A, B and C); however, in the sample E, *P. acidilactici* (86 %) dominated.

Based on the investigations, one can conclude that the lactic microflora of spontaneous rye sourdoughs used for the production of the traditional bread in Lithuania was dominated by *Pediococcus* and *Lactobacillus*: overall, 39 % of the isolates were identified as *P. Pentosaceus*, 18 % as *P. acidilactici* and *L. Farciminis*, 7 % as *L. Curvatus*, 2 % as *L. sakei* and 16 % as *Lactobacillus ssp*.

Table 12.5 Percentage distribution of LAB belonging to different groups in sourdough samples

Samples	Isolates	Groups					
		Nr. 1 *L. farciminis*	Nr. 2 *L. sakei*	Nr. 3 *Lactobacillus* spp.	Nr. 4 *L. curvatus*	Nr. 5 *P. pentosaceus*	Nr. 6 *P. acidilactici*
A	3	–	–	–	–	100	–
B	4	–	–	–	–	100	–
C	6	–	–	–	–	100	–
D	7	–	–	–	–	71	29
E	8	–	–	–	–	25	75
F	4	–	–	–	–	50	50
G	4	100	–	–	–	–	–
H	8	50	–	25	25	–	–
K	12	17	8	58	17	–	–

12.4 Technological Aspects of Traditional Rye Sourdough in the Commercial Bread Process

Today most bakeries use the two-stage sourdough process or multiple-stage rye sourdough process, characterised by continuous propagation. Depending on the bakery, the sourdough is either liquid (palpable; dough yield 300) or stiff (dough yield 170).

In the two-stage sourdough process, sourdough (fermented scald) is made as in the one-stage process, but it is refreshed before use. In refreshing, a certain portion of saccharafied scald is added to the sourdough (fermented scald), and it is fermented till pH 3.2–3.8 (depending on used LAB). Today the multiple-stage process is used if special aroma preferable for consumers is desired.

Multistage processes for the production of rye bread are outlined in Fig. 12.3.

The recipe of rye bread (kg) in different steps of the process and some technological parameters are presented in the Table 12.6.

The stages and conditions for rye dough preparation with a multiple-stage process are the following:

Scald preparation and saccharification. Scalds are prepared in the scalding machine.

According to the recipe water, sifted rye flour and caraway seeds are added into the scalding machine. Temperature of mixture is adjusted to (66 ± 2) °C by steam

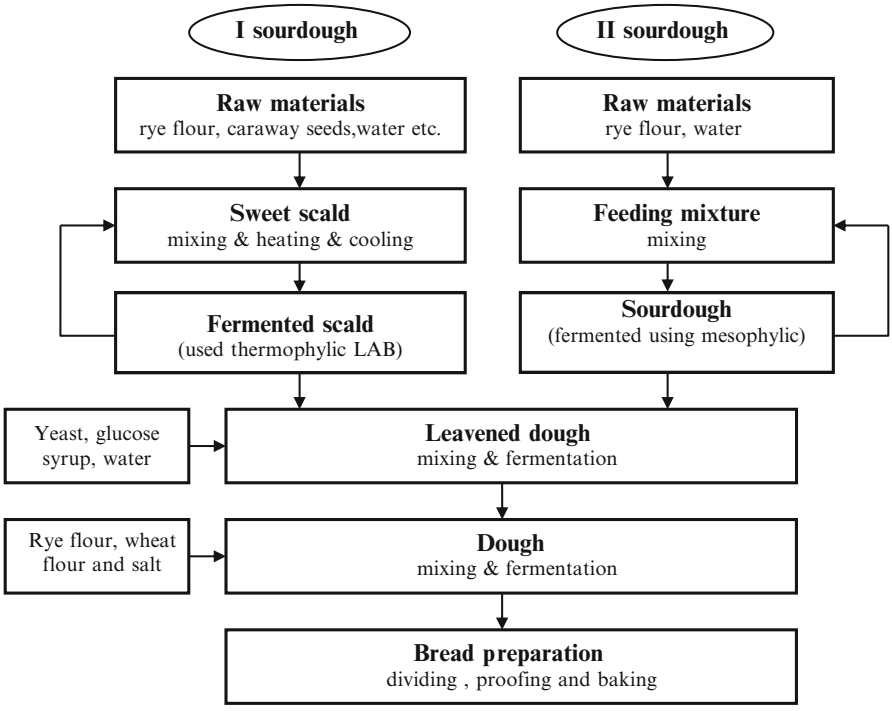

Fig. 12.3 Production of sourdough rye bread using a multistage process

Table 12.6 Recipe and technological parameters of rye bread (kg) using multistage sourdough production (8 %, R700, and 20 %, W10505B)

Raw materials and semimanufactured products, parameters of process	Steps of technological process					
	Sweet scald	Fermented scald	Feeding mixture	Fermented sourdough	Liquid leavened dough	Dough
Sifted rye flour 700	12.0	–	12.0	–	–	56.0
Wheat flour (type 1050B)	–	–	–	–	–	20.0
Water	25.07	–	6.65	–	27.10	–
Caraway seeds (kg)	0.2	–	–	–	–	–
Pressed yeast (kg)	–	–	–	–	0.5	–
Glucose syrup					3	
Salt (kg)	–	–	–	–	–	1.5
Sweet scald (kg)	–	37.27[a]	–	–		–
Fermented scald (kg)	–	74.54	–		37.27	–
Feeding mixture (kg)	–	–	–	18.65[b]		–
Fermented sourdough (kg)	–	–	–	37.27	18.65	
Liquid leavened dough (kg)	–	–	–	–	–	86.52
Saccharification time (min)	60 ± 5	–	–	–	–	–
Fermentation time (min)	–	150 ± 20	–	120 ± 20	90 ± 20	180 ± 20
Temperature (°C)	66 ± 2	49 ± 2	30 ± 2	29 ± 2	29 ± 2	30 ± 2
Moisture (%)	72 ± 2	73 ± 2	45 ± 2	45 ± 2	73 ± 2	47 ± 1
Titrable acidity (°)	–	6 ± 1	–	6.5 ± 1	6.5 ± 1	6.5 ± 1

Remark: Semi-products from previous production: [a]fermented scald or [b]sourdough

in the jacket of the scalding machine. The duration of heating is 30 ± 5 min, and then the scald is mixed throughout and left to cool down to (49 ± 2) °C temperature, which is optimal for scald saccharification (duration 60 ± 5 min).

Fermented scald preparation. The sweet scald is cooled till optimal temperature for thermophylic LAB and added to the tank of the scalding machine, in which 1/2 of fermented scald (TTA of 6.0 ± 1.0) remains. Everything is mixed well. Scald is left to ferment for (150 ± 20) min at (49 ± 1) °C, while TTA of 6.0 ± 1.0 is achieved.

Feeding mixture for sourdough preparation. Sifted rye flour and water are mixed in the scalding machine until a homogenous mass develops. Mixture temperature should be (30 ± 2) °C and moisture (45 ± 2) %. The prepared feeding mixture is pumped to the tank for liquid sourdough fermentation.

Sourdough preparation. One half of the feeding mixture is added to the tank in which 1/2 of the produced sourdough remains (from previous production). Everything is mixed well and then left to ferment for (120 ± 20) min., while TTA of (6.5 ± 1.0) is achieved. The temperature of the liquid sourdough is (29 ± 2) °C.

Leavened dough preparation. The necessary amount (1/2 of the tank) of the fermented scald (TTA 6 ± 1) is added into a tank and cooled down to (29 ± 2) °C temperature. Then the required amount (1/2 of tank) of the fermented sourdough (TTA 6.5 ± 1.0) is added and mixed. The liquid leavened dough is fermented for (90 ± 20) min., while TTA of (6.5 ± 1) is achieved. Yeast is added to the fermented scald and sourdough mixture right before dough preparation and is mixed well.

Dough preparation, dividing, proofing and baking. Dough is mixed in a continuous stirrer or periodical stirrer. After mixing the dough is fermented for (180 ± 20) min. The dough is divided in 0.9 kg pieces using an appropriate equipment, e.g. a BTW II type machine. The mass of the dough pieces depends on the final product (bread) mass, as well as on the accuracy of the dividing machines, mass losses during baking and cooling. Dough pieces are proofed in a conveyer proofing board. Proofing time is (45 ± 5) min (depends on proofing conditions). The optimum proofing conditions for rye dough pieces are temperature (34 ± 2) °C and relative air humidity (66–70 %). Before baking the dough pieces are marked (cutting, pricking) and sprayed with water. Bread is baked in a continuous baking oven and the baking time is approximately (47 ± 2) min.

12.5 Advantages of the Traditional Rye Sourdough Bread Processes

The incorporation of sourdoughs using scald fermentation in rye bread formula is recommended for a more aromatic bread flavour, and this type of sourdough bread has a higher content of volatile compounds and a higher score in sensory tests (Venskaityte et al. 2005). From market studies, it is well known that 85 % of all consumers say that the smell and taste of this type of bread is the most pleasant. The homo-fermentative LAB mainly used for scald fermentation are mostly responsible for acidification of the dough. Sourdough fermented with hetero-fermentative LAB have, aside from a much higher content of acetic acid and ethanol, a higher content of ethyl acetate and ethyl hexanoate compared to sourdoughs fermented with homo-fermentative LAB, which have a higher content of diacetyl and some other carbonyls. When sourdough yeast is added in the preparation of the sourdough (in case of traditional process in leavened dough), the production of ethanol, iso-alcohols, esters and diacetyl increases considerably.

Sourdough addition is the most promising procedure to preserve bread from microbial spoilage (ropiness and mould). Several sourdough LAB produce inhibitory substances in varying degrees such as organic acids (lactic acid, acetic acid), ethanol, diacetyl, hydrogen peroxide and carbon dioxide (Rosenquist and Hansen 1998). Inhibition, however, can also be caused by bacteriocins or bacteriocin-like inhibitory substances (BLIS) (Narbutaite et al. 2008; Digaitiene et al. 2012). Bacteriocins are extracellularly released and ribosomally synthesized low molecule mass peptides or proteins, with a bactericidal or bacteriostatic mode of action, in particular against a wide range of mostly closely related Gram-positive bacteria (Klaenhammer 1993; Savadogo et al. 2006) and even against food-borne pathogens (Garneau et al. 2002), but the producer cells are immune to their own bacteriocins (De Vuyst and Leroy 2007). During recent years, health-conscious consumers are looking for natural food which can fit into their healthy lifestyles. This includes food without additives as chemical preservatives, and so the use of LAB and their antibacterial substances for biopreservation has become more attractive to the food industry (Gálvez et al. 2007; Zotta et al. 2009). Besides, the preparation of bread

with scald results in the reduction of the staling process and retrogradation of the product (Juodeikiene et al. 2011).

The addition of sourdough to the bread recipe has a positive influence on the nutritive value of the bread, as the minerals become bioavailable, and the blood glucose and insulin responses are lowered after eating sourdough bread compared to wheat bread. This effect is believed to be due to the presence of lactic acid formed during fermentation, which will promote interactions between starch and gluten (Östman et al. 2002) during heating, or increases the hardness and decreases the porosity of the bread (Autio et al. 2003). Also, the perceived taste of salt is enhanced in sourdough rye bread compared to wheat bread, so less salt can be added in sourdough rye bread and thus improves the nutritional properties of wholemeal cereals.

References

Autio K, Liukkonen K-L, Juntunen K, Katina K, Laaksonen DE, Mykkänen H, Niskanen L, Poutanen K (2003) Food structure and its relation to starch digestibility, and glycaemic response. In: Proceedings of the 3rd international symposium food rheology and structure (ISFRS 2003). Institute of Food Science and Nutrition, Zürich, pp 7–11

De Vuyst L, Leroy F (2007) Bacteriocins from lactic acid bacteria: production, purification, and food applications. J Mol Microbiol Biotechnol 13:194–199

De Vuyst L, Neysens P (2005) The sourdough microflora: biodiversity and metabolic interactions. Trends Food Sci Technol 16:43–56

Digaitiene A, Hansen A, Juodeikiene G, Josephsen J (2005) Microbial population in Lithuanian spontaneous rye sourdoughs. Ekologia i Technika 13(5):193–198

Digaitiene A, Hansen A, Juodeikiene G, Eidukonyte D, Josephsen J (2012) Lactic acid bacteria isolated from rye sourdoughs produce bacteriocin-like inhibitory substances active against Bacillus subtilis and fungi. J Appl Microbiol 112(5):732–742

Gálvez A, Abriouel H, López RL, Omar NB (2007) Bacteriocin-based strategies for food biopreservation. Int J Food Microbiol 120:51–70

Gänzle MG, Vogel RF (2003) Contribution of reutericyclin production to the stable persistence of *Lactobacillus reuteri* in an industrial fermentation. Int J Food Microbiol 80:31–45

Garneau S, Martin NI, Vederas JC (2002) Two-peptide bacteriocins produced by lactic acid bacteria. Biochimie 84:577–592

Hammes WP, Stolz P, Gänzle MG (1996) Metabolism of lactobacilli in traditional sourdoughs. Adv Food Sci 18:176–184

Hassan YI, Bullerman LB (2008) Antifungal activity of *Lactobacillus paracasei* ssp. *tolerans* isolated from a sourdough bread culture. Int J Food Microbiol 121:112–115

Imbrasiene B (2008) Lithuanian traditional meals. Baltos lankos, Vilnius, 38 p

Juodeikiene G, Salomskiene J, Eidukonyte D, Vidmantiene D, Narbutaitė V, Vaiciulyte-Funk L (2011) The impact of novel fermented products containing extruded wheat material on the quality of wheat bread. Food Technol Biotechnol 49(4):502–510

Katina K, Sauri M, Alakom L, Sandholm MT (2002) Potential of lactic acid bacteria to inhibit rope spoilage in wheat sourdough bread. Lebensm Wiss Technol 35:38–45

Katina K, Arendt E, Liukkonen KH, Autio K, Flander L, Poutanen K (2005) Potential of sourdough for healthier cereal products. Trends Food Sci Technol 16:104–112

Kazanskaya LN, Afanasyeva OV, Patt VA (1983) Microflora of rye sours and some specific features of its accumulation in bread baking plants of the USSR. In: Holas J, Kratochvil F (eds) Developments in food science. Progress in cereal chemistry and technology, vol 5B. Elsevier, London

Klaenhammer TR (1993) Genetics of bacteriocins produced by lactic acid bacteria. FEMS Microbiol Rev 12:39–86

Meroth CB, Walter J, Hertel C, Brandt M, Hames WP (2003) Monitoring the bacterial population dynamics in sourdough fermentation processes by using PCR-denaturing gradient gel electrophoresis. Appl Environ Microbiol 69:475–482

Müller MRA, Wolfru G, Stolz P, Ehrmann MA, Vogel RF (2001) Monitoring the growth of Lactobacillus species during a rye flour fermentation. Food Microbiol 18:217–227

Narbutaite V, Fernandez A, Horn N, Juodeikiene G, Narbad A (2008) Influence of baking enzymes on antimicrobial activity of five bacteriocin-like inhibitory substances produced by lactic acid bacteria isolated from Lithuanian sourdoughs. Lett Appl Microbiol 47(6):555–560

Östman EM, Nilsson M, Liljeberg-Elmstahl HGM, Molin G, Björk IME (2002) On the effect of lactic acid on blood glucose and insulin responses to cereal products: mechanistic studies in healthy subjects and *in vitro*. J Cereal Sci 36:339–346

Röcken W, Voysey PA (1995) Sourdough fermentation in bread making. J Appl Bacteriol 79:38–48

Rosenquist H, Hansen A (1998) The antimicrobial effect of organic acids, sour dough and nisin against *Bacillus subtilis* and *B. licheniformis* isolated from wheat bread. J Appl Microbiol 85:621–631

Rosenquist H, Hansen A (2000) The microbial stability of two bakery sourdoughs made from conventionally and organically grown rye. Food Microbiol 17:241–250

Sadeghi A (2008) The secrets of sourdough: a review of miraculous potentials of sourdough in bread shelf life. Biotechnology 7:413–417

Sahlstrom S, Knutsen SH (2010) Oats and rye: production and usage in Nordic and Baltic countries. Cereal Food World 55(1):12–14

Salovaara H, Katunpää H (1984) An approach to the classification of *Lactobacilli* isolated from Finnish sour rye dough ferments. Acta Aliment Pol 10:231–239

Savadogo A, Outtara Cheik AT, Bassole Imael HN, Traore SA (2006) Bacteriocins and lactic acid bacteria: a mini review. Afr J Biotechnol 5:678–683

Spicher G, Lönner C (1985) Die Mikroflora des Sauerteiges. XXI. Mitteilung: Die Sauerteigen schwedischer Bäckereien vorkommenden *Lactobacillen*. Z Lebensm Unters Forsch 181:9–13

Spicher G, Stephan H (1993) Handbuch Sauerteig, 4th edn. Behr's Verlag GmbH, Hamburg

Stolz B, Böcker G (1996) Technology, properties and applications of sourdough products. Adv Food Sci 18:234–236

Valerio F, Favilla M, De Bellis P, Sisto A, de Candia S, Lavermicocca P (2009) Antifungal activity of strains of lactic acid bacteria isolated from a semolina ecosystem against *Penicillium roqueforti*, *Aspergillus niger* and *Endomyces fibuliger* contaminating bakery products. Syst Appl Microbiol 32:438–448

Venskaityte A, Juodeikiene G, Hansen A, Petersen MA (2005) Application of dynamic headspace technique and gas chromatography: mass spectrometry methods for bread. Ekologia i Technika 13(5):182–186

Zotta T, Parente E, Ricciardi A (2009) Viability staining and detection of metabolic activity of sourdough lactic acid bacteria under stress conditions. World J Microbiol Biotechnol 25:1119–1124