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Review Article

Yeasts Microbiota and Map of Sourdoughs from Türkiye: A Review

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ABSTRACT
Sourdough microbiota determines bread properties such as leavening, aroma, and acid generation. Sourdough bread may also have an important place in nutrition and human microbiota. It is predicted that the difference in nutrition of people in different regions may have an impact on the microbiota. In this study, the sourdough microbiota was mapped by investigating the sourdough microbiota in Türkiye. *Saccharomyces, Candida, Torula,* and *Pichia* are the most targeted yeast genera with *Saccharomyces cerevisiae* being the most isolated in the study. The literature shows the highest species were isolated from the Central Anatolia Region. The most commonly isolated yeast is *Saccharomyces cerevisiae* within all regions. *Torula delbrueckii* and *Pichia guilliermondii* are the most isolated yeasts after *Saccharomyces cerevisiae*. The purpose of this study is to support the future study of topics such as microbiota-based nutritional diet, the relationship of human microbiota with health, and the effects of regionally dominant microbiota on our lives.
Keywords: Sourdough, yeast, microbiota, fermentation, map

Maya Mikrobiyotası ve Türkiye'den Ekşi Maya Haritası: Derleme

ÖZ
Ekşi maya mikrobiyotası ekmeğin mayalanma, aroma ve asit oluşumu gibi özelliklerini belirler. Ekşi mayalı ekmeğin beslenme ve insan mikrobiyotasında da önemli bir yeri olabilir. Farklı bölgelerdeki insanların beslenme farklılıklarının mikrobiyota üzerinde etkili olabileceği öngörülmektedir. Bu çalışmada, Türkiye'deki ekşi maya mikrobiyotası incelenerek ekşi maya mikrobiyotasının haritalaması yapılmıştır. *Saccharomyces*, *Candida*, *Torula* ve *Pichia*, araştırmada en fazla izole edilen *Saccharomyces cerevisiae* ile en çok hedeflenen maya cinsleridir. Literatürde en yüksek türün İç Anadolu Bölgesi'nden izole edildiği görülmektedir. Tüm bölgelerde en sık izole edilen maya *Saccharomyces cerevisiae*'dir. *Torula delbrueckii* ve *Pichia guilliermondii* ise *Saccharomyces cerevisiae*'den sonra en çok izole edilen mayalardır. Bu çalışmanın mikrobiyota temelli beslenme diyeti, insan mikrobiyotasının sağlıkla ilişkisi ve bölgesel olarak baskın mikrobiyotanın hayatımıza etkileri gibi konuların gelecekte yapılacak çalışmalara katkı sağlaması amaçlanmaktadır.
Anahtar kelimeler: Ekşi hamur, maya, mikrobiyota, fermentasyon, harita

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Introduction

Food preservation by fermentation dates back thousands of years (Paul Ross et al., 2002). Fermentation is a process that aids in breaking big organic molecules into smaller ones through the action of microorganisms. For instance, proteins are changed into peptides and amino acids by microbial enzymes, while sugars and starches are transformed into acids and alcohol (Erkmen and Bozoglu, 2016). Fermented foods make up approximately 30% of the human diet (Ros et al., 2021). In Türkiye, mostly, bread and other fermented grain items are made from wheat. In Turkish culture, bread is very important in nutrition (Kabak et al., 2011). The use of sourdough, a traditional baking method, to make sourdough bread has gained popularity recently (Venturini Copetti, 2019; Amr and Alkhamaiseh, 2022; dos Santos et al., 2022).

Sourdough bread can be classified as one of the most important food products among bakery products. The use of sourdough is responsible for leavening dough (Lau et al., 2021). One type of starting culture is sourdough that is made with water, flour (wheat or rye flour), and other ingredients by spontaneous fermentation of microflora (Rosenquist et al., 2000). The microflora of sourdough typically consists of yeasts, and heterofermentative and homofermentative lactic acid bacteria (LAB) (Ventimiglia et al., 2015). Environmental factors are significant for microbial growth and the development of microbiota in the sourdough. There are two categories for these variables: endogenous and exogenous. Endogenous factors are related to pH, water activity, oxidation-reduction potential, nutrients, antimicrobial compounds, and biological structures (Erkmen and Bozoglu, 2016). Exogenous factors are related to storage temperature, relative humidity of the environment, and the concentration of gases in the environment (Yadav et al., 2023). A few factors that influence the yeast diversity in sourdough include the kind of grain, leavening temperature, and dough moisture (Chavan and Chavan, 2011; Urien et al., 2019). Therefore, sourdough microflora differs from environment to environment.

Yeasts have an important role in the microbiome and nutrition of the human body. It seems that the microbiota has a significant impact on both health and sickness (Flint, 2012). All the benefits of sourdough bread depend on the type of yeast genus and species. Therefore, knowing the type of yeast depending on the region provides information about the characteristics of sourdough bread and the selection of yeast culture to produce high-quality sourdough bread. It is intended to investigate the yeast map of sourdough bread due to its growing significance. This review focuses on the yeast map of sourdough microbiota in Türkiye and indicates regional differences and similarities of sourdough yeast microbiota. Among the screening techniques were full-text research articles, theses, and a project dealing with the production and isolation of yeasts from sourdough.

This study is aimed at contributing to the future study of topics such as microbiota-based nutritional diets, the relationship of human microbiota with health, and the effects of regionally dominant microbiota on our lives.

Literature Search Methodology

The timeline of literature review in this research was the initial isolation of yeasts from sourdough, using only the keywords “sourdough”, “yeast isolation from sourdough”, “sourdough microbiota”, “sourdough” and “yeast from sourdough”. Additional literature on these keywords was used only for limited and specific purposes used in sourdough bread production (flour microbes and other components). Peer-reviewed research was obtained from four databases: Google Scholar, Scopus, PubMed, and ScienceDirect. The search strategy included full-text research articles, theses, and projects in English and Turkish. Dataset lists all literature references related to and used in this review, which are included in the Reference section.

Type of Sourdough

Sourdough microflora mostly depends on the type of sourdough. Sourdough production depends on the use of yeast cultures. Depending on the type of sourdough bread, sourdough may be classified into four groups. These are Type I, Type II, Type III, and Type IV. Type I is a traditional method in which microorganisms continuously multiply by replenishing (back-slopping) with fresh flour and water at regular intervals (Lau et al., 2021; Sevgili et al., 2021). The dominant yeasts of the species found in Type I sourdough are *Saccharomyces cerevisiae* and *Candida humilis* (Siepmann et al., 2018). The accelerated sourdough is Type II in liquid form. This sourdough is an industrial process since it involves a single fermentation phase with just lactic acid bacteria (LAB) and yeasts, lasting 15 to 24 hours, followed by back-slopping ones (Yağmur et al., 2016; Sevgili et al., 2021). Type III sourdoughs are powdered, dry sourdoughs that are started by known starter cultures. When baking sourdough bread, they serve as additional acidifiers and scent carriers (De Vuyst and Neysens, 2005). Type IV is the combination of Types I and III. The process of fermentation is initiated by inoculating dough with a microbial starter and is then carried out daily by back-slopping. The dough can be either firm or semi-liquid. It is a common choice for laboratory investigations and is utilized by artisanal bakers most frequently (Catzeddu, 2019).

Properties of Yeasts in Sourdough Fermentation

Yeasts are eukaryotic, unicellular microfungi with significant contributions to the economy, environment, and medicine, and inhabit a broad range of ecological niches, primarily those found in water, soil, air, and on the surfaces of plants and fruits (Erkmen and Bozoglu, 2016). In wheat, rye, and sorghum sourdoughs, yeasts were discovered in levels ranging from 0.1 to 10% of the total counts of microorganisms (Stolz, 2003).

LAB and yeasts play a crucial role in the fermentation process of sourdough (Erkmen and Bozoglu, 2016). The main leavening agent in baked goods is carbon dioxide (CO_2), which is mainly produced by yeasts. The ability of yeasts to leaven food is higher than heterofermentative LAB. Yeasts prefer monosaccharide metabolism (Boudaoud et al., 2021). Additionally, yeasts may support both functional and nutritional characteristics such as the synthesis of vitamins, phytase activity, and the development of phenolic compounds. Yeasts metabolize glucose, fructose, mannose, maltose, and sucrose in flour. They partially metabolize raffinose and do not use pentoses xylose or arabinose (Erkmen and Bozoglu, 2016). Remarkably, strains of *S. cerevisiae* that are used for sourdough have a higher growth rate on maltose, which helps them better adapt to the sourdough environment (Erkmen and Bozoglu, 2016; De Vuyst et al., 2021).

A combination of flour, LAB, and metabolically active yeast is essentially sourdough. The self-releasing dough softens and takes on a different scent after some time when it is allowed to evolve naturally without the addition of yeast. It's the flour, water, and microbes that produce these alterations in the dough. This dough is known as "sourdough" because it tastes sour and ferments on its own. LAB and yeasts are present in sourdough in different amounts and combinations. During the fermentation of sourdough, yeasts, and LABs maintain a symbiotic relationship. Bread's elasticity, acidity, and taste are all impacted by homofermentative LABs' fermentation of sugar to lactic acid. Dough blistering is caused by yeasts and heterofermentative LABs, which also release a lot of lactic acid and other volatile chemicals including CO2, ethyl alcohol, and acetic acid (Erkmen and Bozoglu, 2016).

In recent years, the demand for sourdough bread production is increased owing to natural fermentation, delaying staling, enhancing flavor and aroma, high nutritional value, and healthy properties (Boyaci-gunduz, 2020; De Vuyst and Neysens, 2005). Yeasts ferment the carbohydrates in flour to produce CO_2 and ethanol. CO_2 acts as the primary leavening agent in bread products. Yeasts have a quick fermentation metabolism and can withstand many challenges while baking bread. Nowadays, yeasts play a major role in creating sourdough with better shelf life, osmotolerant qualities, activity retention at low temperatures, and taste production (Urien et al., 2019).

While ethanol strengthens the gluten network and affects the dough's characteristics, a significant amount of it evaporates during baking. As sourdough osmoprotectants, succinate and glycerol both lower pH and affect dough rheology, enhancing gas retention. Yeasts may produce taste metabolites by changing amino acids into higher alcohols and their esters using the Ehrlich pathway (Pico et al., 2015). Additionally, yeasts can create several other metabolites such as ethanol, carbon dioxide, hydrogen peroxide, glutathione, acetic acid, glycerol, flavor compounds, enzymes and trace amounts of organic acids, such as succinic and acetic acids, which slightly acidify the leavened dough and change the final flavor of bread (Jayaram et al., 2013; Jayaram et al., 2014). The antifungal activities of yeast are due to the generation of ethyl acetate lead and releasing phenolic compounds (De Vuyst and Neysens, 2005). Furthermore, following the breakdown of the cell wall, yeasts can release conjugated and bound phenolic acids into free forms, which increases the polyphenol content in cereal products (Palla et al., 2020).

Yeasts in sourdough (SD) show phytase activities that contribute to improving the minerals' bioavailability (magnesium, calcium, iron, and zinc) by breaking down the phytate-mineral complex, which is an antinutritional factor abundant in wholemeal flours. Another activity related to the metabolism of yeasts in sourdough is their ability to increase the content of vitamin B2 (riboflavin) and vitamin D in sourdoughs specifically by *S. cerevisiae*. The concentration of vitamin B9 increases during SD fermentation of oats, barley, and rye, particularly by the presence of *S. cerevisiae* and *Kazachstania humilis* as starter cultures. Yeasts also improve the digestibility of sourdough bread with the production of proteases in sourdough; the proteolysis releases small peptides and free amino acids that are critical for rapid microbial growth, flavor development, and protein digestibility. Additionally, this proteolytic activity might decrease some allergen components, such as gluten (Perez-Alvarado et al., 2022).

In sourdough fermentation, *S. cerevisiae* is relatively acid-tolerant and maltose-positive. It can create an anaerobic environment with CO_2 production that could offer the ideal environment to support *Lactobacillus sanfranciscensis* and *Lactobacillus plantarum* growth compared to aerobiosis (De Vuyst et al., 2021). Similarly, *S. cerevisiae* consumes lactic acid in a dough environment, which delays the acidification brought by LAB and allows the LAB to grow longer in sourdough (Sieuwetrs et al., 2018). The mutual relationship between *Kluyveromyces humilis* and obligately heterofermentative LAB is facilitated by cross-feeding in which obligately heterofermentative LAB hydrolyzes maltose, releasing glucose that becomes readily available for fermentation by maltose-negative *K. humilis* (Carbonetto et al., 2020). *Kluyveromyces unispora* is characterized by restricted substrate utilization, only consuming glucose and fructose. However, its growth in the presence of fructose was higher compared to *S. cerevisiae*. Furthermore, the incapability to ferment maltose can be regarded as a favorable trait in sourdoughs. This is because the yeasts can establish a nutritional mutualism with maltose-positive LAB. It is important to maintain objectivity and avoid subjective evaluations (Korcari et al., 2021). Different types of sourdough yeasts can be classified as maltose-positive and maltose-negative. Through the Emden-Meyerhof-Parnas pathway, maltose-negative yeasts convert glucose into ethanol predominantly. Commonly, sourdough carbohydrates are utilized by maltose-positive yeasts (De Vuyst et al., 2009).

Sourdough Yeast Microbiota and Map

The most common media used in the isolation of yeasts from sourdough in Türkiye were Malt Extract Agar acidified with 10% lactic acid, Dichloran Rose Bengal Chloramphenicol (DRBC) Agar, Malt Extract Broth, yeast extract peptone Dextrose (YPD) broth and Potato Dextrose Agar with incubation at 25-28ºC for 1-5 days. The first yeast isolation from sourdough was performed by Özçelik (2000), and from the sourdough samples, 37 different yeast species were identified.

The regional distribution of the gathered sourdoughs, isolated yeasts, and their references is given in Table 1. A total of 746 yeast isolates were isolated in all of the regions. However, 241 isolates were not determined according to region by Karaman et al. (2018), Boyacı-Gunduz and

Erten (2020), and Aydın et al. (2022) (the yeasts other than *S. cerevisiae* and *P. kudriavzevii*) were not identified. A higher number of samples (44) was collected from the Central Anatolia region, and the number of yeast isolates was 137. The lowest number of samples (14) were obtained from the Marmara region, and the number of yeast isolates was 23. In general, there are either the same or less distinct yeast species isolated from a single sourdough as there are LAB species. Additionally, a single bakery sourdough typically contains at least one or two yeast species (De Vuyst and Neysens, 2005).

Table 1. The regional distribution of the gathered sourdoughs and isolated numbers of yeast in Türkiye

Region	Sourdough numbers of sample	Isolated* numbers of yeast	References
Black Sea	33	93	Aydın et al., 2022; Arici et al., 2018; Karaman et al., 2018; Konuralp, 2020; Yağmur et al., 2016.
Aegean Sea	29	83	Aydın et al., 2022; Bakırcı and Köse, 2017; Karaman et al., 2018; Konuralp, 2020; Yağmur et al., 2016.
Mediterranean Sea	38	112	Aydın et al., 2022; Arici et al., 2018; Boyacı-Gunduz and Erten, 2020; Gül et al., 2005; Karaman et al., 2018; Yağmur et al., 2016.
Marmara	14	23	Aydın et al., 2022; Karaman et al., 2018; Konuralp, 2020.
Central Anatolia	44	137	Aydın et al., 2022; Konuralp, 2020; Sevgili et al., 2021; Yağmur et al., 2016.
Southeast Anatolia	31	50	Aydın et al., 2022; Karaman et al., 2018; Sevgili et al., 2021.
Unknown region	-	241	Karaman et al., 2018; Boyacı-Gunduz and Erten, 2020; Aydın et al., 2022.
Total	189	739	

The pie chart that displays identified yeasts from isolated sourdoughs in Türkiye is seen in Figure 1. According to this, *S. cerevisiae* (397 isolates) was the most isolated species of yeast, the other most isolated yeasts were *Saccharomyces* sp. (21 isolates), *Pichia guilliermondii* (14 isolates), and *Torula delbrueckii* (14 isolates). *Pichia kudriavzevii* was identified 12 isolates throughout the region. In addition, *Debaromyces hansenii* (7 isolates), *Kluyveromyces marxianus* (5 isolates), and *Torula holmii* (4 isolates) were identified. Each of *C. humilis*, *Geotrichum candidum* and *Wickerhamomyces anomalus* were detected as 3 isolates. Each of *K. humilis*, *K. unispora*, *Candida glabrata*, and *Candida parapsilosis* were identified as two isolates.

The maps showing the regional distribution of identified yeasts are given in Figure 2. In the Black Sea region, *S. cerevisiae* and *Torula delbrueckii* were isolated and identified as 83 and 10 isolates, respectively. In the Central Anatolia region, *S. cerevisiae* (107 isolates), *P. kudriavzevii* (9 isolates), *P. guilliermondii* (8 isolates), *K. marxianus* (4 isolates), *Geo. candidum* (3 isolates), *K. unispora* (2 isolates), *Galactomyces candidum* (*Gal. candidum*) (1 isolate), *Candida keyfr* (1 isolate), *W. anomalus* (1 isolate) and *Pichia fermentans* (1 isolate) were identified. In the Mediterranean Sea region, *S. cerevisiae* (81 isolates), *Saccharomyces* spp. (21 isolates), *T. holmi* (4 isolates), *P. guilliermondii* (2 isolates), *C. parapsilosis* (2 isolates), *S. delbrueckii* (19 isolates), and *T. unispora* (1 isolate) were identified. In the Southeastern Anatolia region, *S. cerevisiae* (39 isolates), *P. kudriavzevii* (3 isolates), *W. anomalus* (2 isolates), *K. humilis* (2 isolates), *C. glabrata* (2 isolates), *C. tropicalis* (1 isolate) and *K. marxianus* (1 isolate) were identified. In the Aegean Sea region, *S. cerevisiae* (64 isolates), *Deb. hansenii* (7 isolates), *T. delbrueckii* (4 isolates), *P. guilliermondii* (4 isolates), and *C. humilis* (3 isolates) were identified. Only 23 *S. cerevisiae* were identified from the Marmara region

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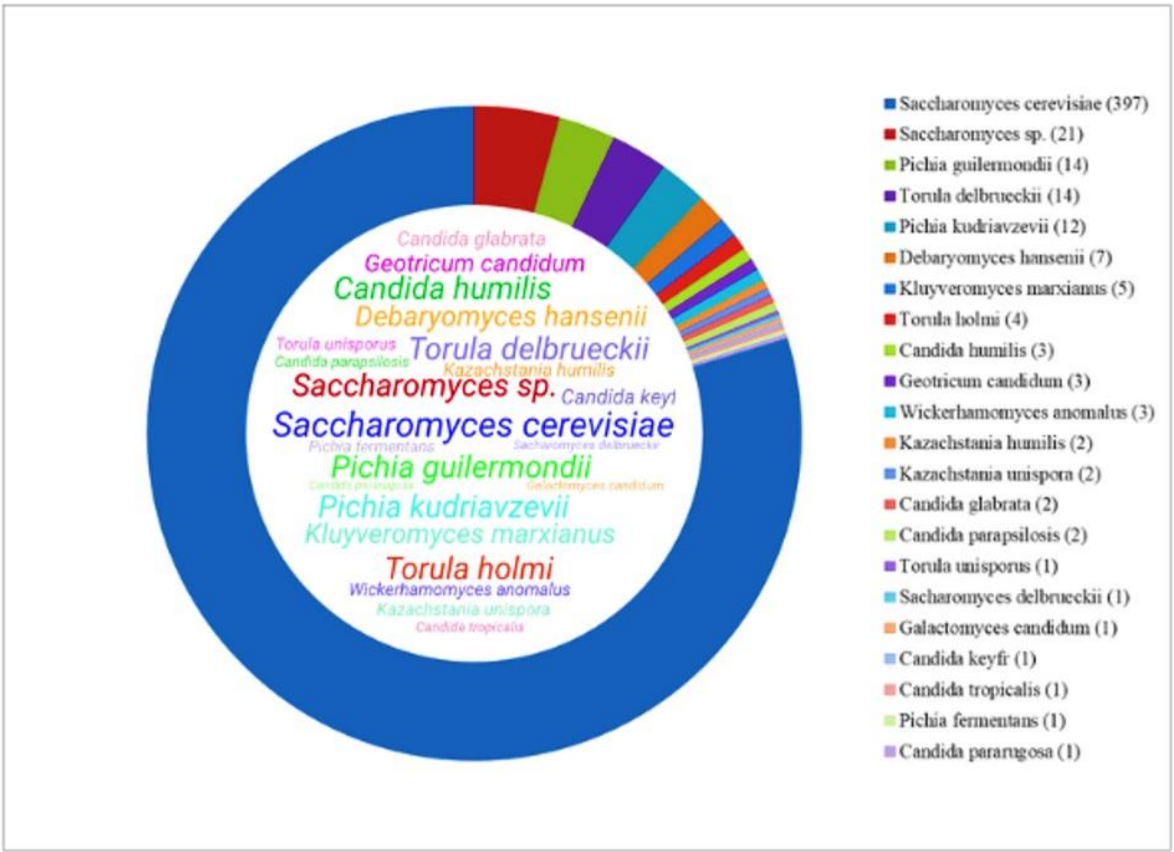

Figure 1. The pie chart displaying isolated yeasts from sourdoughs in Türkiye

Arici et al. (2018) obtained ten sourdough samples from the Black Sea region (Trabzon and Safranbolu) and the Mediterranean region (Isparta) cities. In their laboratory, two sourdoughs were made by the procedure used by artisan bakeries. Wheat flour (from Istanbul) and tarhana were used to produce sourdough. FTIR spectroscopy and 26S rDNA sequencing were used to isolate and identify 26 yeast species. In this research, only two yeast species were isolated from sourdough of the Black Sea and Mediterranean regions: *S. cerevisiae* (13 isolates) and *T. delbrueckii* (6 isolates).

Özçelik (2000) and Gül et al. (2005) obtained ten and fourteen sourdough samples from Isparta. Thirty-seven yeasts were identified by morphological, physiological, and biochemical tests. Most of the isolates were *S. cerevisiae*, which made up 27% (10 isolates) of the isolates and the others were *Torulopsis holmii* (4 isolates), *S. delbrueckii* (one isolate), and *T. unisporus* (one isolate). The other isolates were identified as *Saccharomyces* sp. (6 isolates).

Ten sourdough samples were obtained from İzmir bakeries, and using the Vitek-2 Compact instrument, four distinct yeast species were detected: *D. hansenii* (7 isolates), *S. cerevisiae*

(5 isolates), *C. humulis* (3 isolates), and *T. delbrueckii* (1 isolate) (Bakırcı and Köse, 2017). Thirty-six sourdough samples were obtained from each of the cities Gaziantep, Mardin, and Konya, and 40 yeasts were identified by MALDI-TOF-MS (Sevgili et al., 2021) and PCR (Sevgili, 2023). *P. kudriavzevii* (7 isolates), *K. marxianus* (4 isolates), *G. candidum* (3 isolates), *K. unispora* (2 isolates), *G. candidum* (one isolate), *Candida kefyr* (one isolate) were identified from Konya sourdoughs. *P. kudriavzevii* (3 isolates), *S. cerevisiae* (3 isolates), *W. anomalus* (2 isolates), *K. humilis* (2 isolates), *C. glabrata* (2 isolates), and *C. tropicalis* (one isolate) were identified from Gaziantep sourdoughs. *S. cerevisiae* (8 isolates) and *K. marxianus* (one isolate) were identified from Mardin sourdoughs. More yeast species were isolated from Konya sourdoughs, while *S. cerevisiae* was not isolated.

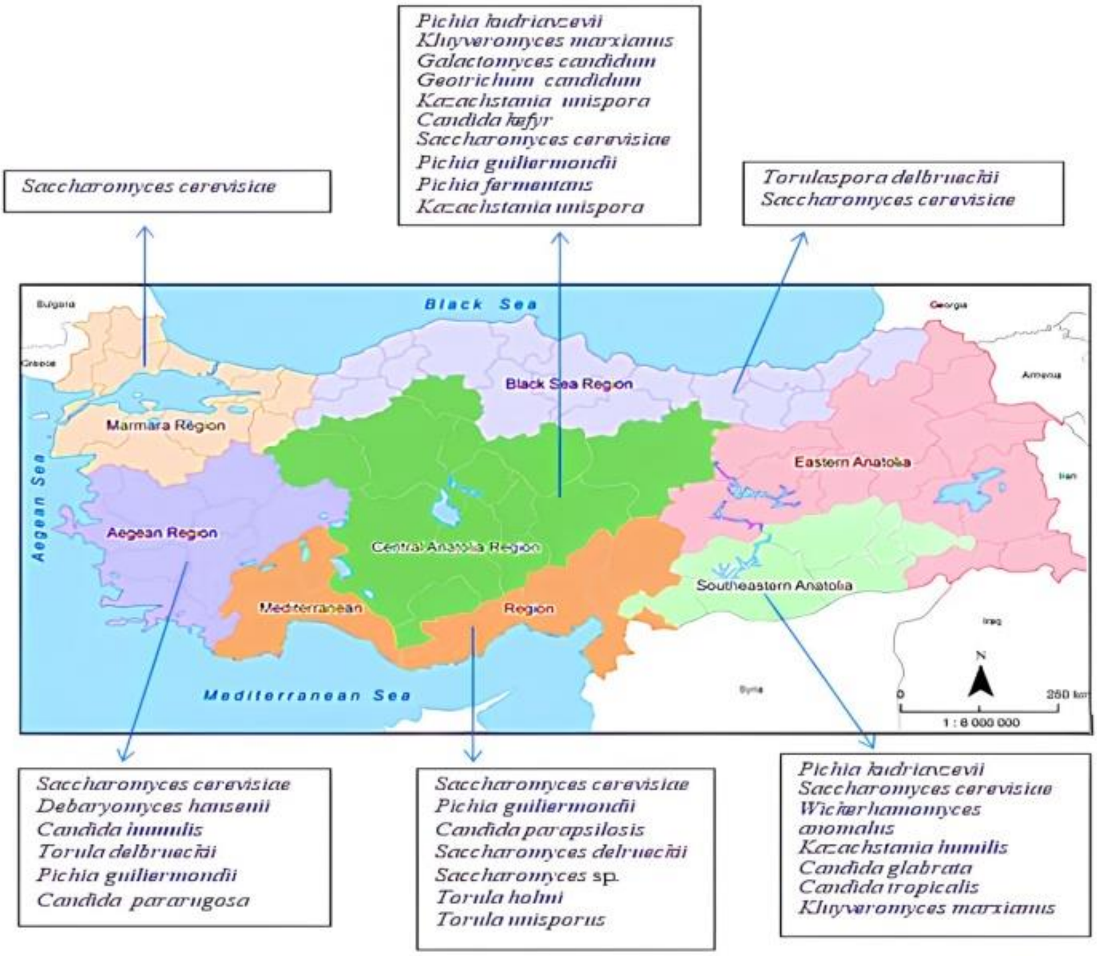

Figure 2. The map showing the regional distribution of identified yeasts

Yeast isolation was made from sourdoughs prepared from wheat flour obtained from 6 different regions of Türkiye. Sourdoughs (from Ankara) and wheat flour (from Izmir, Düzce, Balıkesir, Bolu, Konya, Kastamonu) were used to isolate yeast species, and using MALDI-TOF MS, yeast species were identified (Konuralp, 2020). *S. cerevisiae* was isolated from Ankara (2 isolates), İzmir (4 isolates), Düzce (one isolate), Balıkesir (one isolate), Konya (one isolate), and Bolu (one isolate). One species of *P. fermentans* and *W. anomalus* were isolated from Ankara.

Karaman (2017) and Karaman et al. (2018) studied the isolation of yeasts from 33 sourdoughs obtained from different cities (Trabzon, Adıyaman, Gaziantep, Ankara, Mersin, Istanbul, Kayseri, Isparta, and Manisa) in Türkiye. Fourty isolates were determined and these isolates were *S. cerevisiae* (36), *S. pastorianus* (1 isolate), *C. glabrata* (1), *K. lactis* (1 isolate), and *P. membranifaciens* (1 isolate) (Karaman et al., 2018). However, yeast distribution according to the province was not indicated in their studies.

Different yeast species were identified from sourdoughs obtained from Trabzon (2 samples), Kütahya (2 samples), Isparta (1 sample), Ankara (2 samples), and Adana (1 sample) by RFLP-PCR. The predominant species, *S. cerevisiae* (58 isolates), was found in every sourdough sample. *P. guilliermondii* was the second most often isolated species with 14 isolates except for the Trabzon sourdoughs. *Torulaspora delbrueckii* (7 isolates) were isolated from four sourdoughs (two from Trabzon and two from Kütahya). *C. parapsilosis* (2 isolates) was isolated from Adana. *C. pararugosa* (one isolate) was isolated from one Kütahya sourdough (Yağmur et al., 2016).

A total of sixty-five samples of sourdough were gathered from the Central Anatolia (20 isolates), the Black Sea (15 isolates), the Mediterranean (10 isolates), the Aegean (10 isolates), the Southeast Anatolia (5 isolates), and the Marmara (5 isolates) regions. *S. cerevisiae* (290 isolates), *K. servazzi* (23 isolates), *K. humilis* (11 isolates), *W. anomalus* (10 isolates), *T. delrueckii* (9 isolates), and *P. kudriavzevii* (2 isolates) were identified by SCOT-PCR analyses. Endogenous *S. cerevisiae* (290 isolates) were isolated: 90 from the Central Anatolia region, 60 from the Black Sea region, 48 from the Mediterranean region, 42 from the Aegean region, 22 from the Marmara region, and 28 from the Southeastern region. *P. kudriavzevii* was identified only from the Central Anatolia region (Aydın et al., 2022). However, for the other yeasts distribution by province was not shown in their study.

Eight sourdough samples (wholemeal wheat and rye sourdough) were obtained from Antalya, Mersin, and Ankara (Boyaci-Gunduz and Erten, 2020). Yeast species were identified by the PCR method. They isolated *S. cerevisiae* (106), *K. bulderi* (11), *P. fermentans* (9), *P. membranifaciens* (8), *K. servazzii* (7), *K. unispora* (4), and *Hanseniaspora valbyensis* (3) from the sourdoughs. The most commonly isolated yeast species were *S. cerevisiae*. However, the yeast distribution according to the province was not indicated in their study.

The first sourdough-specific yeast species isolated from spontaneous sourdoughs *K. exigua* (synonym: *Saccharomyces exigua*) by De Vuyst et al., (2016). The most common yeast species from sourdoughs were *S. cerevisiae*, *C. humilis*, *P. kudriavzevii*, *K. exigua*, *T. delbrueckii*, *C. colliculosa*, and *W. anomalus* (Stolz, 2003). Huys et al. (2013) isolated *S. cerevisiae*, *C. humilis*, *P. kudriavzevii*, *K. exigua*, *T. delbrueckii*, and *W. anomalus* from sourdoughs. De Vuyst et al., (2021) have also isolated several yeast species from sourdough, but among them, only *K. exigua*, *C. humilis*, and *C. krusei* species are thought to be fundamental in the fermentation process. Arora et al. (2021) reported 312 research articles about the microbiological and biochemical characterization of sourdough in the world. They indicated 80 yeast species found throughout the world for sourdough. They mainly belong to *Saccharomyces*, *Candida*, *Kazachstania*, *Torulopsis*, *Yarrowia*, and *Pichia* genera. In another study (Pulvirenti et al., 2004), the most common yeast species isolated from sourdoughs are *S. cerevisiae, Candida krusei, Kazachstania exigua, Pichia anomala*, *Pichia subpelliculosa*, *K. exigua*, *Candida holmii* (synonym: *Torulaspora holmii*) and *C. humilis*. In Türkiye, 8 research articles, one project, and 4 theses were produced on isolation from the literature about the isolation and identification of yeast species from sourdoughs. The genera *Saccharomyces*, *Candida*, *Torula*, and *Pichia* was the most frequently targeted, and the most study isolated *S. cerevisiae*.

Based on a study of 287 sourdough recipes published since 1971, the most often occurring yeast species in spontaneously formed stable sourdoughs are listed below (in decreasing order of abundance): *S. cerevisiae*, *C. humilis*, *W. anomalus*, *T. delbrueckii*, *K. exigua*, *P. kudriavzevii*, and *C. glabrata* (De Vuyst et al., 2016). Certain yeast species, like *W. anomalus*, must be regarded as generalists as they can survive in a variety of microbiological environments (Daniel et al., 2011); others, like *C. humilis* and *K. exigua*, are well suited to the sourdough habitat and its surroundings (Lhomme et al., 2016).

Conclusion

This study reviewed the sourdough microbiota reported in the literature, which originated from sourdough samples collected from different regions of Türkiye. The literature shows that the highest species were isolated from the Central Anatolia Region, the Mediterranean Sea, and the Aegean Region. The most commonly isolated yeast is *S. cerevisiae* in all regions. *T. delbrueckii* and *P. guilliermondii* are the most isolated yeasts after *S. cerevisiae*. Yeast is a significant component for sourdough bread production. Sourdough bread will also have an important place in nutrition and human microbiota. It is predicted that the difference in nutrition of people in different regions may have an impact on the microbiota. For this reason, bread, which has an important and leading place in nutrition in Türkiye, is a matter of curiosity. The increasing demand for healthy foods in recent years has sparked interest in sourdough microbiota with beneficial metabolic properties. This research will provide favorable information about the origins of the most favorable yeasts that can be used for more healthful sourdough bread production.

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