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REVIEW ARTICLE

Traditional fermented beverages from Mexico as a potential probiotic source

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Abstract Fermentation is one of the oldest ways of processing food. Some fermented food is produced industrially, but can also be produced in an artisanal way by certain ethnic groups, called traditional fermented foods. In Mexico, there are a variety of traditional fermented beverages which are produced in an artisanal way. They include those made with maize (*atole agrio*, *pozol*, and *tesgüino*), fruit (*tepache* and *colonche*), and obtained by plant fermentation (*pulque*, *tuba*, and *taberna*). These beverages have been used since ancient times for religious and medicinal purposes. The medicinal effect may be due to fermented microorganisms. The presence of beneficial microorganisms known as probiotics provides beneficial effects to consumer health, improving the balance of intestinal host, and reducing the risk of gastrointestinal diseases, mainly. Most probiotics belong to the genus *Lactobacillus*, but *Bifidobacterium*, *Bacillus*, and yeast are also found. Therefore, it is important that the microbiological diversity of the beverages is studied and documented. This review includes information on the microbial diversity and probiotic potential of the most important traditional fermented beverages from Mexico.

Keywords Traditional fermented beverages · Probiotics · Yeast · Bacteria

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Introduction

Fermentation is one of the oldest processes for processing and preserving food. The use of microorganisms to prepare food has been known worldwide for thousands of years. The fermented microorganisms can proceed from the natural microbiota or a starter (Sangwan et al. 2014). During this process, the metabolic activities of microorganisms improve the safety, nutritional, and sensory properties of different raw materials, such as dairy products, meat, vegetables, tubers, and cereals, so these microorganisms have significant contributions in the human diet (Sanni et al. 2013; Chilton et al. 2015). These foods are appreciated for their attributes of flavor, aroma, and pleasant texture, and improved cooking and processing properties (Holzapfel 2002).

Fermented foods are accessible to many people, such as those produced industrially (wine, cheese, beer, bread, and yogurt). However, the so-called "traditional fermented foods" are produced in an artisanal or semi-commercial way by certain social or ethnic groups (Olivares-Illana et al. 2002), proving to be part of the gastronomic culture of certain social groups. Several authors point to these foods as an example of "biological ennoblement" due to bioenrichment with essential nutrients during fermentation (Platt 1964). In addition to being a source of beneficial microorganisms which have an important role in food preservation, palatability, and nutrient bioavailability (Champagne et al. 2005), fermented food is also a source of probiotics which have been defined by experts from the Food and Agriculture Organization of the United Nations (FAO)/World Health Organization (WHO) in 2001 as "live microorganisms which when administered in adequate amounts confer a health benefit on the host".

Around the world, there are about 3500 traditional fermented foods from cereals, legumes, tubers, and fruits, where a consortium of bacteria, yeast, and molds are involved, which may have beneficial effects on consumer health (Escalante et al. 2008; Schoustra et al. 2013; de Vuyst et al. 2014), improving the balance of intestinal host and reducing the risk of gastrointestinal diseases (Chiang and Pan 2012). They also relieve lactose intolerance, improve bioavailability of nutrients, and prevent or reduce the prevalence of allergies. Antimutagenic, hypocholesterolemic, antihypertensive, and immunomodulatory effects have also been reported in probiotics (Chiang and Pan 2012). They relieve symptoms of inflammatory bowel disease, irritable bowel syndrome, colitis, and reduce the risk of colon, liver, and breast cancers (Prado et al. 2008). Several studies have indicated the presence of microorganisms that, although not classified as probiotics due to the lack of sufficient evidence, have certain probiotic characteristics (Table 1).

Consequently, the probiotic consumption, from fermented food and beverages, exert a beneficial effect. So, the aim of this review is to ascertain the information available in the studies about microbial diversity involving potentially probiotic microorganisms in the fermentation of traditional Mexican beverages. All this with the aim of studying new sources of probiotics and rescue a part of culture, like traditional food, that has been lost with the industrialization of food.

Microorganisms with probiotic potential in fermented foods and beverages

Most probiotics belong to the lactic acid bacteria (LAB) group and to the genus *Lactobacillus* (*Lb.*), but not exclusively (Prado et al. 2008). *Lactobacillus* has been isolated in fermented foods and beverages from around the world, but also the genera *Lactococcus* (*Lc.*), *Leuconostoc* (*L.*), *Streptococcus*, and *Enterococcus* have species considered as probiotic (Hill et al. 2014; Holzapfel and Wood 2014). The LAB group is characterized by the production of organic acids during fermentation, mainly lactic acid, which lowers the pH of the substrate, inhibiting the growth of other microorganisms, including pathogens (Holzapfel et al. 1995).

Bifidobacterium is also present in some fermented foods (Tamang 2010). For years, it has been included in the LAB group; however, it belongs to an entirely different phylum (*Actinobacteria*). *Bifidobacterium* is usually found in the gastrointestinal tract, and its presence is related to reducing the incidence of enteric infections and, generally, intestinal health, so it is added to foods, mainly in milk, for their probiotic functions (Hutkins 2006).

Species of the genus *Bacillus* (*B.*) are abundant in foods, mainly in alkaline fermentations (Tamang 2015). Species that have been isolated from vegetable fermentations are *B. cereus*, *B. amyloliquefaciens*, *B. circulans*, *B. coagulans*, *B. firmus*, *B. licheniformis*, *B. megaterium*, *B. pumilus*, *B. subtilis*, and *B. thuringiensis* (Kubo et al. 2011). *Bacillus cereus*, *B. pumilus*, and *B. subtilis* have been considered as species with probiotic effects; however, the fact that they are spore-producing organisms generates conflicting opinions (Zhu et al. 2016).

On the other hand, yeast can also be used as probiotics; however, despite their wide distribution and importance in the production of foods and beverages worldwide, their probiotic potential is ignored (Chen et al. 2010). *Saccharomyces cerevisiae* var. *boulardii* is the only recognized and characterized probiotic yeast (Hatoum et al. 2012), although other species of the genus *Saccharomyces* (*S.*) have probiotic properties, as well as the genera *Pichia*, *Metschnikowia*, *Yarrowia*, *Candida*, *Debaryomyces*, and *Kluyveromyces*, which have been reported in fermented foods and beverages (Tamang and Fleet 2009; Chen et al. 2010; Lv et al. 2013).

Traditional fermented beverages from Mexico

In Mexico, there are about 200 fermented foods and beverages, but only a few have been studied (Herrera 2003).

A wide variety of beverages with historical importance, such as *pulque*, and beverages with cultural importance, such as *pozol* and *tesgüino*, among others, are produced in Mexico (Escalante et al. 2004; Hui and Özgül Evranuz 2012). These traditional fermented beverages have been consumed for years and are strongly related to Mexican culture and traditions.

Traditional fermented beverages have had a great importance in the daily lives of Mexican indigenous communities. Since pre-Hispanic times, Mesoamerican civilizations fermented a variety of plants, cereals, native fruits, and other raw material for beverage production, and the consumption of these played an important role in religion, ritual, divinity, and healing for millennia (Bruman 2000).

Cereals

There is a wide variety of traditional fermented non-dairy beverages produced around the world. Many of them are non-alcoholic beverages made from cereals as raw material. Cereals have been a part of the staple diet in Mexico for centuries, mainly maize (Elizaquível et al. 2015), playing an important role in the nutrition of marginalized population (Jideani and Jideani 2011).

Cereal fermentation is carried out mainly by species of LAB and yeasts (Corsetti and Settanni 2007). The genera *Enterococcus*, *Lactococcus*, *Lactobacillus*, *Leuconostoc*, *Pediococcus*, *Streptococcus*, and *Weissella* are commonly associated with fermentation. These genera include some probiotic species (Table 2; Guyot 2010; Moroni et al. 2011).

Although the population of LAB is dominated by the genus *Lactobacillus* (de Vuyst and Neysens 2005), *Leuconostoc* has been reported as being prevalent in the fermentation of *pozol*

Table 1 Examples of potential probiotic microorganisms in fermented foods from around the world

Product	Country	Substrate	Microorganism	Potential probiotic characteristics	References
Kefir grains	Brazil	Milk	*L. mesenteroides*	Antagonistic activity against pathogens Antibiotic resistance No hemolytic activity	Leite et al. (2015)
			Lc. lactis sp. *cremoris* *Lc. lactis* sp. *lactis*	Antagonistic activity against pathogens Antioxidant activity Antibiotic resistance No hemolytic activity	Leite et al. (2015)
			Lb. paracasei	Antagonistic activity against pathogens Antioxidant activity Bacteriocin No hemolytic activity Adherence to Caco-2 Antibiotic resistance	Leite et al. (2015)
Red wine	Spain	Must	*Pediococcus pentosaceus* *Lb. plantarum*	Survival in GI conditions Adherence to Caco-2 Reduces *E. coli* adhesion	García-Ruíz et al. (2014)
			Lb. casei *Oenococcus oeni*	Survival in GI conditions	García-Ruíz et al. (2014)
Idli	India	Rice and *Phaseolus mungo*	*Candida tropicalis* *Saccharomyces cerevisiae*	Survival in GI conditions Antibiotic resistance Autoaggregation Antimicrobial activity against *Salmonella*, *Staphylococcus aureus*, and *Pseudomonas* sp. Enzymes production B12 vitamin production Cholesterol assimilation	Syal and Vohra (2013)
Jalebi	India	Maida (refined wheat flour)	*Aureobasidium* spp. *Pichia manshurica*	Survival in GI conditions Antibiotic resistance Autoaggregation Antimicrobial activity against *Salmonella*, *Staphylococcus aureus*, and *Pseudomonas* sp. Enzymes production Cholesterol assimilation	Syal and Vohra (2013)
Ricotta cheese	Tunisia	Milk	*Lb. plantarum*	Antimicrobial activity against *Listeria monocytogenes*	Ben Slama et al. (2013)
Fermented olives	Greece	Olives	*Lb. pentosus*, *Lb. plantarum*, *Lb. paracasei* subs. *paracasei*	Survival in GI conditions No hemolytic activity Adherence to Caco-2	Argyri et al. (2013)
Fermented bambangan	Malaysia	Bambangan fruit (*Mangifera pajang*)	*Lb. plantarum* *Lb. brevis*	Survival in GI conditions High percentage of hydrophobicity and autoaggregation Enzymatic activity Antimicrobial activity against *Listeria monocytogenes*	Ng et al. (2015)

Table 1 (continued)

Product	Country	Substrate	Microorganism	Potential probiotic characteristics	References
Raw milk sheep cheese Salami	Italy	Milk Meat	*Lb. plantarum*	Susceptible to antibiotics Survival in GI conditions Agglutinability	Turchi et al. (2013)
Alheira, *Chouriça de Vinhais*, and *Salpicão de Vinhais* (sausages)	Portugal	Meat	*Enterococcus faecium*	Antimicrobial activity against *Listeria monocytogenes*, *Listeria innocua*, and *Staphylococcus aureus* Survival in GI conditions	Barbosa et al. (2014)
Traditional fermented soybean paste	China	Soybean	*Lb. plantarum*	Survival in GI conditions Antimicrobial activity against *Escherichia coli*, *Staphylococcus aureus*, *Salmonella* sp., and *Shigella* sp. Adherence to Caco-2 Inhibits adhesion of pathogens to Caco-2	Li et al. (2015)

Table 2 Microorganisms isolated from some Mexican traditional fermented cereal beverages

Product	Substrate	Sensory properties	Fermentation time	Microorganisms	State	References
Atole agrio	Nixtamalized maize	Acid taste	Until 3 days	*Lb. acidophilus* and *Lb. plantarum*, *Saccharomyces cerevisiae*	Chiapas	Sánchez-Dirzo et al. (2010)
Pozol	Nixtamalized maize	Acid taste, refreshing, non-alcoholic	Until 4 days	*Streptococcus*, *Streptococcus suis*, *S. bovis*, *Enterococcus*, *Exiguobacterium*, *Lc. lactis*, *Lc. raffinolactis*, *L. mesenteroides*, *Lb. confusus*, *Lb. fermentum*, *Lb. plantarum*, *Lb. casei*, *Lb. delbrueckii*, *Lb. alimentarium*, *Bifidobacterium*	Campeche, Chiapas, Oaxaca, Quintana Roo, Tabasco, and Yucatán	Ulloa and Herrera (1972); Wacher-Rodarte et al. (1993); Nuraida et al. (1995); ben Omar and Ampe (2000); Wacher-Rodarte et al. (2000); Escalante et al. (2001); Díaz-Ruíz et al. (2003)
Tesgüino	Germinated maize	Acid taste, refreshing	Until 3 days	*Candida guilliermondii*, *Hansenula anomala*, *S. kluyveri*, *Saccharomyces cerevisiae*	Chihuahua, Durango, Jalisco, Nayarit, Oaxaca, Sinaloa, and Sonora	Ulloa et al. (1987); Lappe and Ulloa (1989); Wacher-Rodarte (1995)

(Nuraida et al. 1995). *Streptococcus* and *Enterococcus* have also been found in traditional cereal-based fermented beverages in Mexico, such as *pozol* (ben Omar and Ampe 2000; Escalante et al. 2001). In this regard, strains of *Streptococcus* genera, *L. pseudomesenteroides* and *Weissella paramesenteroides* isolated from *pozol*, present probiotic potential, since the microorganisms are able to survive under low pH and bile salts conditions and to adhere to HEp2 cells (Rodríguez et al. 2011).

Agrobacterium azotophilium is a bacterium, reported in *pozol*, that have the ability to produce an antimicrobial compound with a broad spectrum (Ray et al. 2000).

Saccharomyces cerevisiae has been present in the fermentation of traditional fermented beverages of Mexico, which is widely recognized as safe for use in food for human consumption and can present probiotic potential. Other yeasts like *S. kluyveri*, *Candida guilliermondii*, and *Hansenula anomala* are also found in traditional fermented beverages of Mexico, and although there have been no studies on their probiotic potential, are good options to consider (Ulloa et al. 1987; Wacher-Rodarte 1995). Meanwhile, *Pichia kudriavzevii* and *Clavispora lusitaniae* have been isolated from *atole agrio*, showing probiotic characteristics (growth capacity at 37 °C, low pH, and in the presence of bile salts survival, and biofilm formation) (Manrique-Donrronsoro et al. 2016).

Fruits

There are a great variety of fermented drinks made with fruits from Africa, Asia, and Latin America. Grape wine is probably the most important fermented drink, economically speaking, although there are also beverages made with fruits such as dates in North Africa, jackfruit in Asia, and pineapple in Latin America (Battcock 1998).

The spontaneous fermentation of these beverages is mainly based on LAB (*Lactobacillus*, *Leuconostoc*, *Pediococcus*, etc.) and yeast (*Saccharomyces*, *Hansenula*, *Candida*, etc.) found on the fruit surface (Table 3; Di Cagno et al. 2013) and in utensils used during processing (Fleet 2003).

Tepache is a traditional Mexican fermented beverage from the pineapple shell. It is a product that can prevent contamination caused by canning industries, since the making of preserves like pineapple in syrup generates a great amount of waste, which can be transformed into a beverage for human consumption, with nutrients and vitamins obtained from fermenting microorganisms. The presence of several species of *Lactobacillus*, such as *Lb. plantarum*, has been reported (Alvarado et al. 2006). In this beverage, bacteriocin-producing bacteria (*Lc. lactis*, *E. faecium*) have also been reported, pointing to the beverage as a natural source of potential antimicrobials (de la Fuente-Salcido et al. 2015). *Leuconostoc mesenteroides* is also present in *tepache*, and is able to produce a bacteriocin named mesentericin, besides

Table 3 Microorganisms isolated from some traditional fermented Mexican beverages made from fruit

Product	Substrate	Sensory properties	Fermentation time	Microorganisms	State	References
Tepache	Pineapple	Refreshing, low alcohol content, sour taste	Up to 3 days	*Lb. plantarum*, *L. mesenteroides*, *Lactobacillus* sp., *Lc. lactis*, *Hanseniaspora*, *Torulopsis inconspicua*, *Saccharomyces cerevisiae*, *Pichia membranaefaciens*, *Candida queretana*		Nava-Garduño (1953); Herrera and Ulloa (1982); Moreno-Terrazas (2005); Alvarado et al. (2006); de la Fuente-Salcido et al. (2015)
Colonche	Red prickly	Sweet and pleasant taste	Up to 3 days	*Candida valida*, *Saccharomyces cerevisiae*, *Torulopsis taboadae*, *Pichia fermentans*	Chihuahua, Sonora, Zacatecas	Diguet (1928); Ulloa and Herrera (1978); Herrera and Ulloa (1981a); Ulloa et al. (1987); Rodríguez-Lerma et al. (2011)

producing dextran, an extracellular polymer that has a wide industrial use as coadjuvant, emulsifier, carrier, and stabilizer, and which may serve as a prebiotic for other beneficial microorganisms (Moreno-Terrazas 2005; Sarwat et al. 2008).

The only yeast recognized as probiotic (*Saccharomyces cerevisiae* var. *boulardii*) was isolated from fruits of Indochina called lychees (Czerucka et al. 2007), and fermented fruit beverages as well as fruits are a source of probiotic microorganisms. As for the traditional fermented beverages of Mexico, *S. cerevisiae* is present in most of them (Corona-González et al. 2013). In addition, *Hanseniaspora*, *Torulopsis inconspicua*, *T. taboadae*, *Pichia membranaefaciens*, *P. fermentans*, and *Candida* species, such as *C. valida*, are also common (Nava-Garduño 1953; Alvarado et al. 2006; Rodríguez-Lerma et al. 2011; de la Fuente-Salcido et al. 2015). *Candida queretana*, identified as a new species, was isolated from P. fermentans in the central Mexican state of Querétaro (Herrera and Ulloa 1982). The search for new potentially probiotic yeasts is very important, since many of the traditional fermented beverages in Mexico are obtained using yeasts as the starter microorganism (Herrera and Ulloa 1982).

Tibicos as starters

Traditional fermented fruit beverages from Mexico are sometimes inoculated with starters called *tibicos*, which play an important role in the fermentation of *tepache* and *colonche*.

Tibicos are macrocolonies, formed by symbiotic associations of bacteria and yeasts, consisting of compact, whitish or yellowish, translucent or opalescent, gelatinous masses crossed by fine veins or irregular shape and size. They are developed in sugary liquids kept at rest, and in fruits and its juices, such as pineapple (Herrera and Ulloa 1981b).

Tibicos are very similar to water kefir grains, in relation to their structure (Magalhães et al. 2010). Fermented beverages with kefir grains, both milk and water, have been shown to improve health. Furthermore, potentially probiotic cultures have been isolated from these (Zanirati et al. 2015), indicating that *tibicos* may present microorganisms with probiotic potential.

Yeasts such as *Brettanomyces claussenii*, *Candida guilliermondii*, *C. valida*, *Cryptococcus albidus* var. *bidus*, *Rhodotorula rubra*, and *S. cerevisiae*, and bacteria such as *B. brevis*, *B. polymyxa*, *B. circulans*, *B. coagulans*, *B. firmus*, *B. macerans*, and *B. pumilus* (Rubio et al. 1993) have been isolated from *tibicos* used for the fermentation of fruit beverages, although this microbial composition could vary at the species level, depending on each local product (Herrera and Ulloa 1981b).

Since *tibicos* are very popular and important in the preparation of traditional fermented beverages, it would be necessary to study the potential probiotic of such strains.

Plants

In Mexico, fermented beverages made from other sources such as agave, coconut palm, or coyol palm are also consumed, and will be discussed below (Table 4).

Pulque is one of the oldest beverages in Mexico and is obtained from the fermentation of the agave sap called *agua miel*. Microorganisms that are part of this fermentation are homo- and heterofermentative LAB (*Lb. acidophilus*, *Lb. hilgardii*, *Lb. plantarum*, *Lb. acetolerans*, *Lb. kefir*, *Lc. lactis* sp. *lactis*, *L. citreum*, *L. kimchii*, *L. mesenteroides*, *L. pseudomesenteroides*), an alcohol-producing bacteria (*Zymomonas mobilis*), γ-proteobacteria, *Acetobacter malorum*, *A. pomorium*, *Microbacterium arborescens*, *Flavobacterium johnsoniae*, *Gluconobacter oxydans*, and *Hafnia alvei* (Sánchez-Marroquín 1967; Sánchez-Marroquín et al. 1967; Ulloa and Herrera 1976; Chellapandian et al. 1988; Escalante et al. 2004, 2008), besides yeasts, mainly of the genus *Saccharomyces* (*S. bayanus*, *S. cerevisiae*, *S. paradoxus*) and others like *Candida* spp., *C. parapsilosis*, *Clavispora lusitaniae*, *Hanseniaspora uvarum*, *K. lactis*, *K. marxianus*, *Pichia membranaefaciens*, *Pichia* spp., and *Torulaspora delbrueckii* (Cervantes-Contreras and Pedroza-Rodríguez 2007; Lappe-Oliveras et al. 2008), that have been found in raw material such as *agua miel*; in this case, *L. mesenteroides* with probiotic potential has been reported in *agua miel*, as well as in *pulque* fermentation (Castro-Rodríguez et al. 2015; Giles-Gómez et al. 2016). *Lactobacillus casei* J57 (GenBank accession no. JN182264) was also reported in *pulque*, showing bile salt hydrolase activity, a characteristic associated with the probiotic potential of bacteria, due to an association with serum cholesterol-lowering effects (González-Vázquez et al. 2015; Patel et al. 2010). In this beverage, *Lb. sanfranciscensis* was also found. This bacteria showed anti-inflammatory properties in an in vivo model in mice (Torres-Maravilla et al. 2016).

On the other hand, the yeast *Kluyveromyces marxianus* isolated from *pulque* presented probiotic characteristics such as antagonistic activity against *Klebsiella pneumoniae*, as well as adhesion to gut mice, mainly (Mendoza-Gardeazábal 2013).

On the other hand, the fermented beverage from palm juice is known worldwide as "palm wine", taking different names according to the region and the type of palm from which it is made, for example, *toddy* or *tari* in India, *mu*, *bandji*, *ogogoro*, *nsafufuo*, *nsamba*, *mnazi*, *yongo*, *tua*, or *tubak* in West Africa and South America (Ouoba et al. 2012).

In Mexico, palm wines are called *taberna*, which is obtained from the palm of coyol, and *tuba*, obtained from the coconut palm. These are artisanal beverages. For this reason, there is little information on the microbial diversity of palm wines made in Mexico. However, it was noted the presence of *Lc. lactis* and *E. faecium*, bacteria with antimicrobial activity due

Table 4 Microorganisms isolated from some traditional fermented Mexican plants

Product	Substrate	Sensory properties	Fermentation time	Microorganisms	State	References
Pulque	Agave	Alcoholic beverage, white, viscose, and strong smell	Until 1 day	*Lb acidophilus*, *Lb. hilgardii*, *Lb. plantarum*, *Lb. acetolerans*, *Lb. kefir*, *Lc. lactis* sp., *L. citreum*, *L. kimchii*, *L. mesenteroides*, *L. pseudomesenteroides*, *Zymomonas mobilis*, *Acetobacter malorum*, *A. pomorium*, *Microbacterium arborescens*, *Flavobacterium johnsoniae*, *Gluconobacter oxydans*, *Hafnia alvei*, *S. bayanus*, *S. cerevisiae*, *S. paradoxus*, *Candida* spp., *C. parapsilosis*, *Clavispora lusitaniae*, *Hanseniaspora uvarum*, *K. lactis*, *K. marxianus*, *Pichia membranaefaciens*, *Pichia* spp., *Torulaspora delbrueckii*	Center of Mexico	Sánchez-Marroquín (1967); Sánchez-Marroquín et al. (1967); Ulloa and Herrera (1976); Chellapandian et al. (1988); Escalante et al. (2004, 2008); Cervantes-Contreras and Pedroza-Rodríguez (2007); Lappe-Oliveras et al. (2008)
Taberna	Coyol palm	whitish, effervescent, sweet	1 day	*Fructobacillus durionis*, *F. fructosus*, *Acetobacter pasteurianus*, *Lb. nagelii*, *Lb. sucicola*, *Zymomonas mobilis*, *Saccharomyces cerevisiae*, *Hanseniaspora guilliermondii*, *Candida tropicalis*, *C. intermedia*, *Kazachstania unispora*, *Kazachstania exigua*, *Meyerozyma guilliermondii*, *Pichia kudriavzevii* (*Issatchenkia orientalis*), and *Pichia kluyveri*	South of Mexico	Balick (1990); Alcántara-Hernández et al. (2010); Santiago-Urbina et al. (2015)
Tuba	Coconut palm	Alcoholic beverages, sweet	Not reported	*Saccharomyces cerevisiae*, *L. lactis*, and *E. faecium*	Colima, Michoacán, and Guerrero	Stringini et al. (2009); Velázquez-Monreal et al. (2011); Chandrasekhar et al. (2012); Santiago-Urbina et al. (2013); de la Fuente-Salcido et al. (2015)

to bacteriocin production, in *tuba* (de la Fuente-Salcido et al. 2015). This is in addition to other investigations where the presence of *Lb. pentosus*, *Lb. plantarum*, and *L. brevis* with important characteristics are to be considered as potential probiotics, in palm wines in other parts of the world (Fossi et al. 2015). This suggests that palm wines, made in Mexico, could be sources of microorganisms with probiotic potential.

Conclusion

In Mexico, there are indigenous groups which use fermented foods and beverages for stimulating, ritual, nutritional, and medicinal purposes. These effects could be associated with microorganisms that carry out the fermentation. So, this review shows traditional fermented beverages from Mexico as a potential source of probiotics. One way to rescue this heritage is to industrialize the production of these beverages, for which it would be necessary to isolate, characterize, and optimize starter cultures, obtaining in this way an added value to the beverages when using microorganisms with probiotic characteristics, bringing health benefits. However, it is necessary to know, in advance, the diversity and probiotic potential of those bacteria and yeasts involved in the fermentation of beverages, and, thus, achieve an improvement and enhancement in traditional technologies, offering added value by having a beneficial effect on the consumer. These processes also achieve a rescue of traditions and cultural heritage, and, in some cases, the use of agro-industrial waste.

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