AGRICULTURAL SCIENCE AND TECHNOLOGY, VOL. 13, No 2, pp 212-216, 2021
Published by Faculty of Agriculture, Trakia University, Bulgaria
ISSN 1313-8820 (print)
ISSN 1314-412X (online)
http://www.agriscitech.eu
DOI: 10.15547/ast.2021.02.034

Case Study

Isolation of *Lactobacillus* species from fermented *Parkia biglobosa* seed and screening for their probiotic activity

K. Kuti[1], I.M. Hussaini[1]*, A. Usman[2], A. Isa[1]

[1]Department of Microbiology, Faculty of Life Sciences, Ahmadu Bello University, Zaria, Nigeria
[2]Department of Microbiology, Faculty of Science, Kaduna State University, Kaduna, Nigeria

(Manuscript received 24 December 2020; accepted for publication 10 May 2021)

Abstract. *Food fermentation has been a tradition for decades due to its immense benefits. Lactic acid bacteria are known to possess probiotic potential due to various chemical antimicrobial substances they produce. This research was aimed at isolating Lactobacillus spp. from locally fermented locust beans and screening the isolates for their probiotic potential. A total of 20 samples of fermented locust beans (P. biglobosa) were collected and processed. The samples were inoculated onto de-Mann Rogosa Sharpe (MRS) media and incubated anaerobically. The isolates with characteristic colonial morphology of Lactobacillus sp. were characterized using Gram staining and biochemical tests. Lactobacillus spp. isolates were screened in-vitro for probiotic potential using the following parameters, tolerance of low pH, bile tolerance and antimicrobial activity. Four isolates of Lactobacillus species consisting of Lactobacillus fermentum and Lactobacillus plantarum were isolated from different fermented locust beans. All isolates showed tolerance to low pH and bile concentration of 3.04 and 0.3%, respectively. The Lactobacillus species isolates showed varying antibacterial activity against all test bacteria with isolate S06 (L. plantarum) showing the highest degree of antibacterial activity. In conclusion, the Lactobacillus species isolated from fermented locust beans can serve as probiotic candidate.*

Keywords: antimicrobial activity, fermentation, local locust beans, potential, probiotic

Introduction

Parkia biglobosa is a tropical plant known to be indigenous to Africa and was named after its discoverer Mungo Park (a Scottish physician) by Robert Brown (Ajayi et al., 2015). It is well-known and used in Nigeria and other African countries including Senegal, Mali, Sudan, Ghana, Guinea Bisau and Cameroon amongst others (Olujobi, 2012). Fermented *Parkia biglobosa* seed is known by different names in various Nigerian dialects: iru in Yoruba, dawa dawa in Hausa and daddawa in Igbo (Ojewumi et al., 2016). It is known to be high in nutritional value, hence a reason for its use as a food source especially in developing or underdeveloped countries as it serves as a cheap source for protein. It is known for a considerable amount of proximate constituent in its different parts (i.e. crude fibre, crude protein, crude fat and moisture content) vitamins and minerals (Olujobi, 2012; Ojewumi et al., 2016).

Parkia biglobosa seed is traditionally fermented to produce a local condiment (iru dadawa or ogiri) by moist solid state fermentation known for its overtone production of ammonia due to hydrolysis of amino acids during fermentation. A process known to be a classical alkaline fermentation with pH ranging from 6.0-8.39. This is responsible for the fermented locust bean organoleptic property resulting in characteristic taste and sweet aroma when used to cook local dishes (Adelekan and Nwadiuto, 2012).

Probiotics are defined by WHO as live microbial food supplements which, when administered in adequate amounts, confer a health benefit on the host (Shehata et al., 2016). Among the usually used microorganisms, lactic acid bacteria (LAB) are regarded as a major group of probiotic bacteria. Probiotics are non-pathogenic, technologically suitable for industrial processes, acid tolerant, bile tolerant and produce antimicrobial substances (Mojgani et al., 2015). They are classified as generally recognized as safe (GRAS) microorganisms because of their long and safe use as starter cultures in fermented products (Shehata et al., 2016).

Probiotics are a promising natural source of conferring health benefits. They can be sourced from human, animal and some fermented food products. It is important to note that although there are different genera of microorganisms with probiotic potential, they are strictly strain specific and a consideration in their biosafety. The following are genera of bacteria with recognized probiotic potential *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Pediococcus*, *Enterococcus* and *Streptococcus*, all of which belong to a general group, lactic acid bacteria (LAB). Other genera are *Bifidobacterium*, *Saccharomyces, Escherihia* and *Bacillus* (Sabina, 2014).

*e-mail: hussainiibrahim269@gmail.com

Lactobacillus species and other LAB isolated from fermented seeds and foods have been screened for their probiotic potential by different researchers. Pundir et al. (2013) reported that LAB isolated from different food samples exhibited excellent probiotic potentials. Species of *Lactobacillus* isolated from fermented curly kale juice (Szutowska and Gwiazdowska, 2021), Brazilian regional ovine cheese (Meira et al., 2012) and fermented African locust bean seeds (Nwagu et al., 2020) all had promising results as probiotic candidates.

LAB have become the most widely used probiotics for medicine and food production. As probiotics, firstly, the microorganisms must be non-pathogenic and non-toxigenic; secondly, they should withstand external and internal environments, including gastric acid and bile salts. In addition, the adhesive ability of LAB is a primary consideration in the selection of probiotics (Saad et al., 2013).

The sources of LAB are diverse. The natural environment, intestinal tracts of mammals, and fermented foods are all sources of LAB. Fermented dairy products, especially fermented milk and cheese, are the main sources of LAB (Ji et al., 2015; Stojanovski et al., 2021). Fermented meat products, especially fermented sausages, are also an excellent source. Some studies have isolated and identified LAB from fermented sausages (Han et al., 2017; Stojanovski et al., 2020).

This research was carried out to determine the probiotic potential of *Lactobacillus* species isolated from fermented *Parkia biglobosa* seeds.

Material and methods

Sample collection

A total of 20 samples of locally fermented *Parkia biglobosa* beans were collected from within and outside Zaria, Kaduna central market and stored in the refrigerator prior to use.

Isolation of Lactobacillus species

For each of the 20 samples, 10 g was appropriately weighed and aseptically transferred into labelled conical flask containing 90 mL of sterile peptone water and homogenized. A sterile syringe was used to transfer 1 mL into 9 mL sterile peptone water to obtain 10^{-1} dilution. Further dilutions were carried out serially from 10^{-1} to 10^{-4}, then 0.1 mL aliquot of dilution 10^{-4} were spread onto de-Mann Rogosa Sharpe (MRS) media (Himedia, USA) and incubated at 37°C or 48 hrs (Shehata et al., 2016).

Characterization of Lactobacillus species

The isolates were characterized based on their colonial morphology on MRS medium, Gram reaction and biochemical reactions (Catalase, Methyl-Red, Voges-Proskeur, Citrate Utilization and Sugar Fermentation Test) (Cowan and Steel, 2003).

Evaluation of the isolates probiotic ability

Preparation of phosphate buffer saline solution: Phosphate saline solution was prepared by dissolving 2 phosphate buffer saline tablets into 200 mL distilled water and dispensed into 3 separate conical flasks. Dilute 0.1M of NaOH and 0.1M HCl was used to adjust the pH of the phosphate buffer contained in a separate conical flask to pH 7.22 and 3.04, respectively intended for use for the physiological test. The third was adjusted to pH 6.5. All were autoclaved at 121°C at 15 psi for 15 min.

Acid tolerance test: The acid tolerance test was performed by the viable plate count method as described by Maragkoudakis et al. (2006) with modification. Overnight bacterial cell culture grown in MRS broth at 37°C were harvested by centrifuging at 10,000 rpm at 4°C for 10 min. Supernatant was discarded and cell suspension was washed twice with phosphate buffer saline (PBS) (Sigma-Aldrich, USA) of pH 7.22 and re-suspended in PBS of pH 3.04 for 3 hrs. Aliquot of the cell suspension was plated on sterile MRS agar plates both at 0 hr and 3 hrs. Plates were incubated anaerobically at 37°C for 24 hrs.

Bile tolerance test: Ability of the isolates to tolerate bile was also determined by the viable plate count method. Overnight MRS broth culture of the bacterial cells were harvested at 10,000 rpm at 4°C for 10 min washed twice with PBS of pH 7.22 before being resuspended in PBS solution containing 0.3% Oxgall bile (Sigma-Aldrich, USA). Cell aliquot was plated at 0 hr and 4 hrs on sterile MRS agar plate and incubated at 37°C for 24 hrs (Maragkoudakis et al., 2006).

Antimicrobial activity of the Lactobacillus isolates

The Oxford cup assay was used as reported by Wang et al. (2009). Test bacteria that were used for the antibacterial activity were *Pseudomonas aeruginosa* and *Salmonella* spp. *Lactobacillus* species isolates were subcultured prior to use in the experiments. Isolates were incubated on MRS medium and incubated anaerobically. The bacterial cultures were centrifuged at 10,000 rpm for 10 min. Supernatants were filtered through a 0.45-μm filter paper. The inoculum of indicator (pathogen) were each seeded on the surface of sterile Muller-Hinton plates. Cork borer was heat sterilized and used to bore well on the agar plate. About 10 drops of cell free culture suspension (CFCs) were transferred into well using sterile syringe. Chloramphenicol disc (Oxoid, UK) was aseptically placed at the center of each plate to serve as a positive control while the plate for the negative control was done using sterilized normal saline. The plates were incubated for 18-24 hrs at 37°C. Antibacterial activity was indicated by the observation of zones of inhibition. The diameter of inhibition zones were measured in millimeter (mm). Zone diameters ≥5 mm were considered positive for inhibitory activity while zone diameters ≤4 mm were considered negative for inhibitory activity.

Results

Isolation and identification Lactobacillus species

The cultural, microscopic and the biochemical characteristics of the different isolates of *Lactobacillus* species from different samples of locally fermented locust beans are shown in Table 1. Four isolates from different samples had the characteristic colonial appearance of *Lactobacillus* species on MRS Agar. Further characterization of these isolates microscopically and biochemically revealed that two of the isolates were *L. fermentum* while the remaining two isolates were *L. plantarum.*

Table 1. Cultural, microscopic and biochemical characteristics of bacterial isolates from fermented locust beans

Isolates code	Cultural characteristic	Gram reaction	Cat	MR	VP	Cit	Suc	Ara	Gal	Glu	Lac	Dex	Inference
S01	Yellow, irregular moist	G+ rods	-	+	-	-	+	+	+	+(AG)	+	+	*L. fermentum*
S02	Milky white, raised, moist	G+ rods	-	+	-	-	+	+	+	+	+	+	*L. plantarum*
S06	Milky white, smooth, moist	G+ rods	-	+	-	-	+	+	+	+	+	+	*L. plantarum*
S08	Whitish, flat and moist	G+ rods	-	+	-	-	+	+	+	+(AG)	+	+	*L. fermentum*

Key: G+= Gram Positive, Cat= Catalase, MR= Methyl Red, VP= Voges-Proskauer, Cit= Citrate utilization, Suc= Sucrose fermentation, Ara= Arabinose fermentation, Gal= Galactose fermentation, Glu= Glucose fermentation, Lac= Lactose fermentation, Dex= Dextrose fermentation, AG= Acid and Gas production.

Physiological characterization of the Lactobacillus species isolated

The *Lactobacillus* species isolated were screened for their ability to survive the simulated condition of the gastrointestinal tract, which included ability to tolerate low pH and bile which are characteristics of the gut. All four *Lactobacillus* species isolated were found to tolerate low pH of 3.04 and bile concentration of 0.3% as presented in Table 2.

Table 2. Physiological characteristic of *Lactobacillus* isolates

Isolates	Low acid tolerance (pH 3.0)	Bile tolerance (0.3%)
S01 (*L. fermentum*)	+	+
S02 (*L. plantarum*)	+	+
S06 (*L. plantarum*)	+	+
S08 (*L. fermentum*)	+	+

Key: + = isolate tolerates the condition

Antibacterial activity of the Lactobacillus species isolated from fermented P. biglobosa

The antimicrobial activity of the 4 *Lactobacillus* species isolates against three (3) isolates of *Pseudomonas* spp. and one (1) isolate of *Salmonella* spp. is illustrated in Table 3 and Figure 1. Isolate S06 (*L. plantarum*) had antibacterial activity against all test bacteria with inhibitory zones ranging from 11 mm to 12 mm. Isolates S02 (*L. plantarum*) and S08 (*L. fermentum*) had activity against at least three of the test bacteria with inhibitory zones ranging from 10 to 18 mm and 5 to 20 mm, respectively. Isolate S01 (*L. fermentum*) had zones of inhibition ranging from 6 to 15 mm but no activity against *Salmonella* spp. and one of the *P. aeruginosa* tested.

Table 3. Antibacterial activity of isolates against *Salmonella* spp. and *P. aeruginosa*

Isolates / test organism	Mean zones of inhibition (mm)			
	P. aeruginosa	*P. aeruginosa*	*Salmonella* spp.	*P. aeruginosa*
S01 (*L. fermentum*)	15	6	0	0
S02 (*L. plantarum*)	18	0	15	10
S06 (*L. plantarum*)	12	12	11	12
S08 (*L. fermentum*)	20	5	7	0

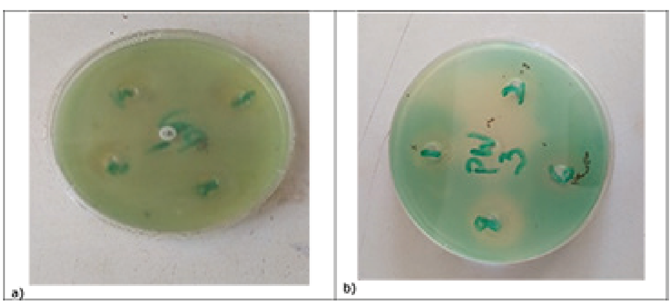

Figure 1. Antibacterial activity of *Lactobacillus* species against: (a) *Salmonella* species and (b) *Pseudomonas aeruginosa*

Discussion

In this study, four *Lactobacillus* species were isolated from locally fermented locust beans. Two isolates were found to be *Lactobacillus fermentum* and the remaining two were *Lactobacillus plantarum.* These species of *Lactobacillus* are among the normal microbiota of fermented foods. *Lactobacillus plantarum* is among the most frequently isolated species of LAB from fermented foods (Xiong et al., 2012; Hutkins, 2019; Szutowska and Gwiazdowska, 2021). Similarly, Stojanovski et al. (2020, 2021) reported that *L. plantarum* was the most commonly isolated *Lactobacillus* species from homemade raw sausages and homemade white sheep‘s milk cheeses, respectively.

Ability of potential probiotic isolates to tolerate acidic condition and bile salt is commonly used to detect the viability and activity of probiotic organisms. Survival of the isolates at pH 3.0 is considered the optimal acid tolerance for the selected probiotic strains. All the *Lactobacillus* species isolated were able to tolerate pH 3.0, hence they are acid tolerant *Lactobacillus* strains. This result is in line with the report of Azat et al. (2016) who isolated acid tolerant *Lactobacillus* species from traditionally fermented Xinjiang cheese.

All the test *Lactobacillus* species screened in this study were able to tolerate 0.3% of bile salt. This means the isolates can survive in GIT since *Lactobacillus* strains, which grow and metabolize in normal physical bile concentration, could survive in gastrointestinal transit. This is in agreement with the findings of Meira et al. (2012) and Azat et al. (2016).

Bile tolerance is usually considered a basic property of probiotic bacterial strains, as this property enables them to survive in the small intestine. In the human gastrointestinal tract, the mean bile concentration is about 0.3% and is considered crucial and high enough to screen resistant strains (Azat et al., 2016).

Antibacterial activity is an important property of potential probiotic bacteria as this property will inhibit the growth of pathogenic organisms and prevent gastrointestinal infection. The isolates produce various antimicrobial substances which create unfavorable conditions for the growth of pathogens as well as toxigenic and pathogenic organisms in humans and/or animals (van der Meulen et al., 2007).

Results from the antibacterial screening in this study revealed variability in the antibacterial activities of the 4 *Lactobacillus* isolates against *P. aeruginosa* and *Salmonella* spp. The inhibition of growth of the test pathogens by the *Lactobacillus* isolates suggests that they have antimicrobial activity and can inhibit the growth as well as the proliferation of pathogenic bacteria. Susceptibility of *P. aeruginosa* to *Lactobacillus* species observed in this study is similar to the reported by Szutowska and Gwiazdowska (2021). Inhibitory activity of *Lactobacillus* species against clinical and environmental isolates of *E. coli* was previously reported by Atta et al. (2020).

The variation in inhibitory activity of *Lactobacillus* species observed in this study indicated that the antibacterial activity of *Lactobacillus* species is strain dependent. A similar phenomenon was also observed by Patel et al. (2014), Atta et al. (2020) and Szutowska and Gwiazdowska (2021).

Lactobacillus plantarum S06 inhibited the growth of the test bacteria in this study. This might be linked to the bacteriocin production ability of *Lactobacillus plantarum* as reported by other researchers (da Silva Sabo et al., 2014; Biswas et al., 2017; Yi et al., 2020; Szutowska and Gwiazdowska, 2021).

The antibacterial property of the *Lactobacillus* species isolated might be due to the production of metabolites. Metabolites such as lactic acid, acetic acid, diacetyl, fatty acids, aldehydes, bacteriocins, and other compounds, among which, lactic acid, acetic acid, and bacteriocins are the most active antimicrobial compounds produced by *Lactobacillus* species (Kumari et al., 2012). Production of lactic and acetic acid by LAB lowers the pH of the surrounding thereby inhibiting pathogens and spoilage microorganisms in food especially fermented foods (Reis et al., 2012). These organic acids inhibit the proliferation of bacteria by penetrating the bacterial cell membrane and result in cytoplasmic acidification as well as inhibition of the activities of enzymes (Cervantes-Elizarrarás et al., 2019).

Conclusion

Four isolates of *Lactobacillus* spp. consisting of two *Lactobacillus fermentum* and *Lactobacillus plantarum* were isolated from fermented locust beans seed. All of the four isolates tolerated low pH, 0.3% bile salt and show different degree of inhibitory properties against *Pseudomonas aeruginosa* and *Salmonella* species.

References

Adelekan OA and Nwadiuto E, 2012. Bacterial Succession Studies during Fermentation of African Locust Bean (*Parkia biglobosa*) to Iru using molecular methods. British Biotechnology Journal, 2, 49-59.

Ajayi OA, Akinrinde IM and Akinwunmi OO, 2015. Towards the development of shelf stable 'iru' (*Parkia biglobosa*) condiment bouillon cubes using corn, cassava and potato starch extracts as binders. Nigerian Food Journal, 33, 67-72.

Atta HI, Gimba A and Bamgbose T, 2020. Antimicrobial activity of lactic acid bacteria isolated from garri on *Escherichia coli* strains isolated from clinical and environmental samples. Agricultural Science and Technology, 12, 357-363. https://doi.org/10.15547/ast.2020.04.057

Azat R, Liu Y, Li W, Kayir A, Lin D-B, Zhou W-W and Zheng X-D, 2016. Probiotic properties of lactic acid bacteria isolated from traditionally fermented Xinjiang cheese. Journal of Zhejiang University-SCIENCE B (Biomedicine & Biotechnology), 17, 597-609.

Biswas K, Upadhayay S, Rapsang GF and Joshi SR, 2017. Antibacterial and synergistic activity against β-Lactamase-producing nosocomial bacteria by bacteriocin of LAB isolated from lesser known traditionally fermented products of India. Hayati Journal Biosciences, 24, 87-95.
https://doi.org/10.1016/j.hjb.2017.08.008

Cervantes-Elizarrarás A, Cruz-Cansino NS, Ramírez-Moreno E, Vega-Sánchez V, Velázquez-Guadarrama N, Zafra-Rojas QY and Piloni-Martini J, 2019. *In vitro* probiotic potential of lactic acid bacteria isolated from aguamiel and pulque and antibacterial activity against pathogens. Applied Sciences, 9, 1-11. https://doi.org/10.3390/app9030601

Cowan ST and Steel KJ, 2003. Manual for the Identification of Medical Bacteria (edited and reviewed by G.I. Barrow and R.K.A. Feltham), 3rd edition, Cambridge University Press, London, UK.

da Silva Sabo S, Vitolo M, González JMD and Oliveira RPS,

2014. Overview of *Lactobacillus plantarum* as a promising bacteriocin producer among lactic acid bacteria. Food Research International, 64, 527-536. https://doi.org/10.1016/j.foodres.2014.07.041

Han Q, Kong B, Chen Q, Sun F and Zhang H, 2017. *In vitro* comparison of probiotic properties of lactic acid bacteria isolated from Harbin dry sausages and selected probiotics. Journal of Functional Foods, 32, 391-400

Hutkins R, 2019. Microbiology and Technology of Fermented foods. 2nd edition, IFT Press, Wiley, New York, USA.

Ji K, Jang NY and Kim YT, 2015. Isolation of lactic acid bacteria showing antioxidative and probiotic activities from kimchi and infant feces. Journal of Microbiology & Biotechnology, 25, 1568-1577.

Kumari A, Kunzes A, Monika S and Tek C, 2016. Probiotic characterization of lactic acid bacteria isolated from fermented foods and partial purification of its bacteriocin. CIBTech Journal of Biotechnology, 5, 8-16.

Maragkoudakisa PA, Zoumpopouloua G, Miarisa C, Kalantzopoulosa G, Potb B and Tsakalidoua E, 2006. Probiotic potential of *Lactobacillus* strains isolated from dairy products. International Dairy Journal, 16, 189-199.

Meira SMM, Helfer VE, Velho RV, Lopes FC and Brandelli A, 2012. Probiotic potential of *Lactobacillus* spp. isolated from Brazilian regional ovine cheese. Journal of Dairy Research, 79, 119-127.

Mojgani N, Fatimah HF and Vaseji N, 2015. Characterization of indigenous *Lactobacillus* strains for probiotic properties. Jundishapur Journal of Microbiology, 8, 1-2.

Nwagu TN, Ugwuodo CJ, Onwosi CO, Inyima O, Uchendu OC and Akpuru C, 2020. Evaluation of the probiotic attributes of Bacillus strains isolated from traditional fermented African locust bean seeds (*Parkia biglobosa*), "daddawa". Annals of Microbiology, 70, 20.

Ojewumi ME, Omoleye JA and Ajayi AA, 2016. The effect of different starter cultures on the protein content in fermented African locust bean (*Parkia biglobosa*) seeds. International Journal of Engineering Research and Technology, 5, 1-6.

Olujobi OJ, 2012. Comparative evaluation of nutritional composition of African locust bean (*Parkia biglobosa*) fruits from two locations. Nigerian Journal of Basic and Applied Science, 20, 195-198.

Patel A, Prajapati JB, Holst O and Ljungh A, 2014. Determining probiotic potential of exopolysaccharide producing lactic acid bacteria isolated from vegetables and traditional Indian fermented food products. Food Bioscience, 5, 27-33. https://doi.org/10.1016/j.fbio.2013.10.002

Pundir RK, Rana S, Kashyap N and Amandeep Kaur A, 2013. Probiotic potential of lactic acid bacteria isolated from food samples: an in vitro study. Journal of Applied Pharmaceutical Science, 3, 85-93. doi: 10.7324/JAPS.2013.30317

Reis JA, Paula AT, Casarotti SN and Penna ALB, 2012. Lactic acid bacteria antimicrobial compounds: characteristics and applications. Food Engineering Reviews, 4, 124-140. https://doi.org/10.1007/s12393-012-9051-2

Saad N, Delattre C, Urdaci M, Schmitter JM and Bressollier P, 2013. An overview of the last advances in probiotic and prebiotic field. LWT-Food Science and Technology, 50, 1-16.

Sabina F, 2014. Microorganisms with claimed probiotics properties: An overview of recent literature. International Journal of Environmental Research and Public Health; 11, 4745-4767.

Shehata MG, El Sohaimy SA, El-Sahn MA and Youssef MM, 2016**.** Screening of isolated potential probiotic lactic acid bacteria for cholesterol lowering property and bile salt hydrolase activity. Annals of Agricultural Science, 61, 65-75.

Stojanovski S, Cilev G, Trajanoska B, Stamatova-Yovcheva K and Yovchev D, 2020. Diversity of *Lactobacillus* microflora in homemade raw sausages during the ripening. Agricultural Science and Technology, 12, 371-374. https://doi.org/10.15547/ast.2020.04.059

Stojanovski S, Cilev G and Trajanoska B, 2021. Isolation and characterization of *Lactobacillus* microflora from homemade white sheep's milk cheeses during ripening. Agricultural Science and Technology, 13, 79-82. https://doi.org/10.15547/ast.2021.01.015

Szutowska J and Gwiazdowska D, 2021 Probiotic potential of lactic acid bacteria obtained from fermented curly kale juice. Archives of Microbiology, 203, 975-988.

van der Meulen R, Scheirlinck I, van Schoor A, Huys G, Vancanneyt M, Vandamme P and Vuyst LC, 2007. Population dynamics and Metabolite target analysis of lactic acid bacteria during laboratory fermentations of wheat and spelt sourdoughs. Applied Environmental Microbiology, 73, 4741-4750.

Wang Y, 2009. Prebiotics: Present and future in food science and technology. Food Research International, 42, 8-12.

Xiong T, Guan Q, Song S, Hao M and Xie M, 2012. Dynamic changes of lactic acid bacteria flora during Chinese sauerkraut fermentation. Food Control, 26, 178-181. https://doi.org/10.1016/j.foodcont.2012.01.027

Yi L, Qi T, Hong Y, Deng L and Zeng K, 2020. Screening of bacteriocin producing lactic acid bacteria in Chinese homemade pickle and dry-cured meat, and bacteriocin identification by genome sequencing. LWT- Food Science and Technology, 125, 109177. https://doi.org/10.1016/j.lwt.2020.109177