



United States Department of Agriculture

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ABUNDANCE AND FUNCTION OF LACTIC ACID BACTERIA IN THE SOIL TO THE VEGETABLES CONSUMPTION CONTINUUM



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Opportunities to discover biofunctions in LAB that colonize plants, foods and the human gut

■ Microbes in Plants

- *Microbial diversity on fresh vegetables primarily derives from the soil. A low incidence of lactic acid bacteria occurs in fresh vegetables.*

■ Microbes in Fermented Vegetables

- *Lactic acid bacteria consistently prevail in vegetable fermentations.*

■ Microbes in the Human Gut

- *Lactobacillus plantarum will continue to be central to the ability of fermented vegetables to deliver beneficial health effects.*

Cucumber Microbiome



Rhizosphere effect

-Soil: Bacteroidetes & Actinobacteria

-Rhizoplane: *Rhizobium*, *Cellvibrio*, *Saccarophagus*, *Devosia*, *Pseudomonas*

(Ofek and others, 2014. *Env. Microbiol.* 16(7) 2157)

Seeds (59 isolated cultures)

-Dried Seeds: *Bacillus* & *Paenibacillus*

-Residual placenta and fruit pulp:

Lactococcus, *Cronobacter*, *Pantoea*, Enterobacteriaceae & *Pseudomonas*

-Fresh Seeds: *Microbacterium* (Khalaf & Raizada, 2016. *BMC Microbiol.* 16:131)

Harvested Fruits

-*Rhizobium*, *Pseudomonas*, *Pantoea*, & *Stenotrophomonas* (Pérez-Díaz and others, 2018. *Int. J Food Microbiol. Submitted*)

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Fermented Fruits

-Early Fermentation:

Pseudomonas, *Pantoea*, *Stenotrophomonas*, *Comamonas*, *Acinetobacter*, *Wautersiella*, *Microbacterium*, *Flavobacterium*, *Enterobacter*, *Ochrobactrum*, *Citrobacter* and *Kluyvera*

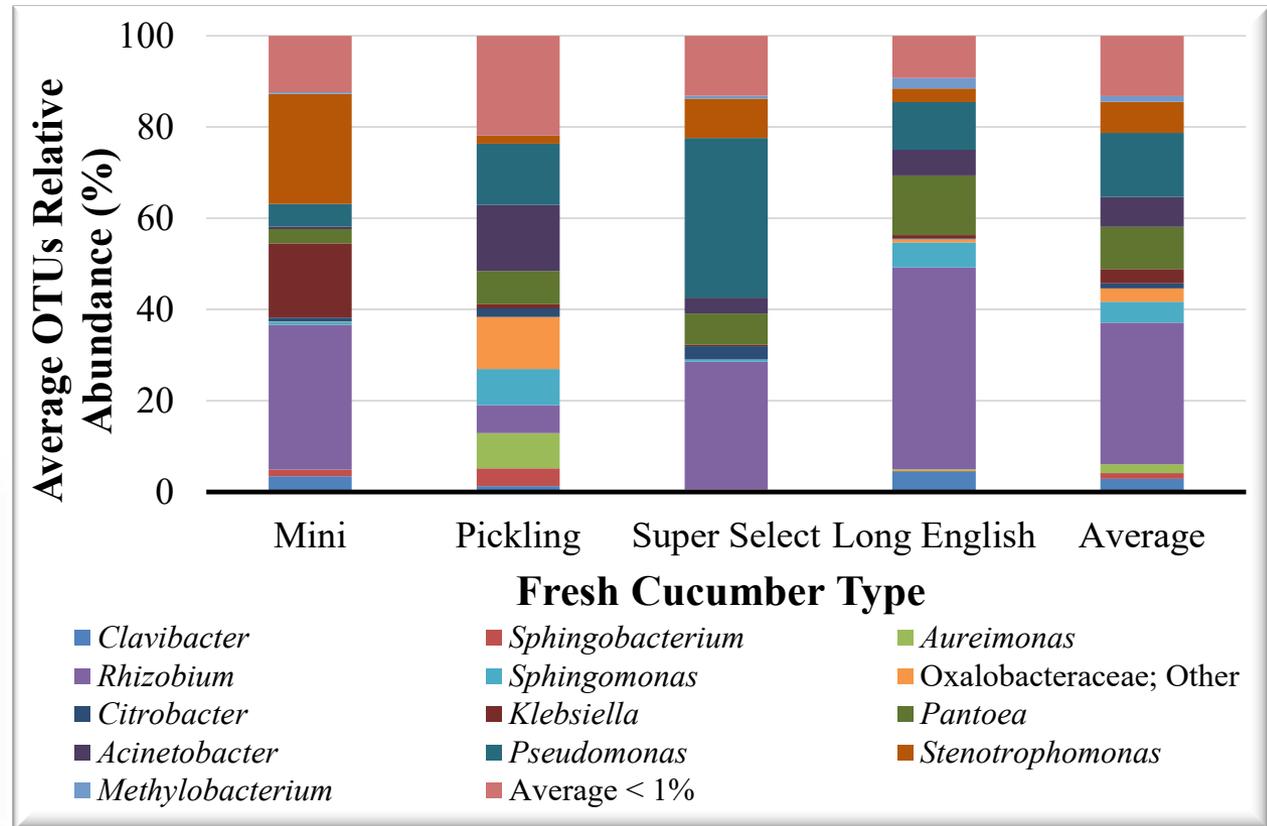
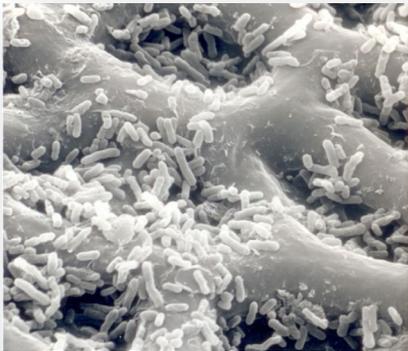
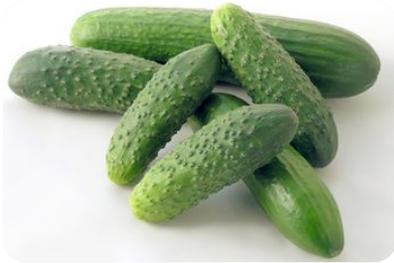
(Pérez-Díaz and others, 2018. *Int. J Food Microbiol. Submitted*)

-Active Fermentation:

Lactobacillus pentosus, *Lb. plantarum*, *Lb. brevis*, *Weissella* spp., *Pediococcus ethanolidurans*, *Leuconostoc* spp. and *Lactococcus* spp.

(Pérez-Díaz and others, 2017. *Food Microbiol.* 63:217)

Microbes in Fresh Cucumbers



The core bacteriome of fresh vegetables including fresh cucumbers, corn, cabbage, carrots, spinach and peas is composed of two taxonomical families, *Enterobacteriaceae* and *Pseudomonadaceae* (Lopez-Velasco et al., 2013; Manani et al., 2006; Samish and Etinger-Tulczynsky, 1962; Shi et al., 2009; Weiss et al., 2007).

Symbiotic relationship between plants and microbes

Microbes Contribute to:

- Growth (auxin hormone)
- Development
- Defense

Plants Evolve to:

- Select Beneficial Microbes
- Maintain Beneficial Microbes
- Sustain Valuable Microbes

Dried seeds, richer in oil (50%), protein (35%) and DNA are an important vectors of microbial diversity for plants, flowers and fruits (Lemanceau et al., 2017).

Examples of microbial functions in plant systems

Microbes	Function	Outcome	Reference
<i>Pseudomonadaceae</i> (20% of the rhizoplane population)	degrade plant cell wall components and other complex polysaccharides	enables the microbe to penetrate and colonize the plant tissue	DeBoy et al., 2008
<i>Bacillus</i>	nitrogen-fixation and scavenging, deaminase activity and protease, pectinase or cellulose activity	conversion of Nitrogen gas into a solid and usable form	DeBoy et al., 2008
<i>Bacillus</i> spp., <i>Enterobacteriaceae</i> and Lactic Acid Bacteria	phosphate solubilization through the production of organic acids or phosphatases	availability of Phosphate	Khalaf and Raizada, 2016
<i>Enterobacteriaceae</i> and <i>Pseudomonas</i>	produce auxin and siderophores	plant growth hormone and iron chelation	Khalaf and Raizada, 2016

Bacillus species isolated from cucumber seeds cluster apart from *Bacilli* isolated from other cucurbit seeds (Khalaf and Raizada, 2016). *Bacillus* species isolated from cucumber seeds cluster apart from *Bacilli* isolated from other cucurbit seeds (Khalaf and Raizada, 2016).

Lactic acid bacteria response to various stresses on the vegetation results in:

- nutrient enhancement
- stress reduction
- and consequently plant growth promotion

(Filannino et al., 2018)

Concomitantly, the plant produced food is enriched in bioavailable and bioactive compounds.

Fermentation serves as an instrument to pre-adapt beneficial microbes indigenous to fresh vegetables to:

- The acidic pH characteristic of the colon
- The high lactic acid concentration present in the colon
- The metabolism of dietary fiber, particularly pectic substances naturally present in the plant material and the gut.
- LAB from plants augment the catalog of metabolic functions needed in & available to the gut for building resilience in a healthy individual.

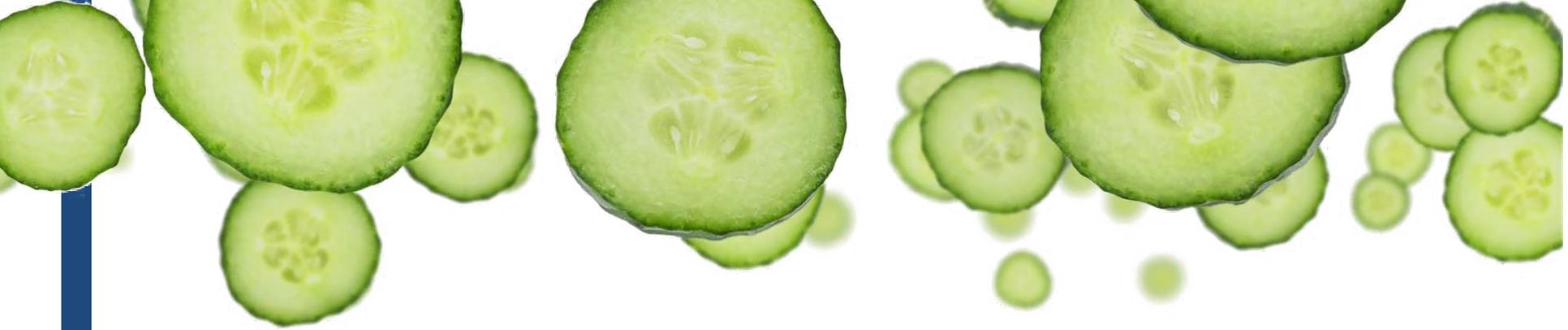


LAB are naturally present in Human

- Human Body 10^{14}
 - Stomach 10^7
 - Lower Small Intestine 10^7
 - Colon 10^{11}
 - Skin 10^4 to 10^5
 - Saliva 10^4 to 10^5
 - Dental plaque 10^4 to 10^5
 - Upper Small Intestine 10^4 to 10^5 (Sender et al., 2016)
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- The number of LAB rarely reach 10^9 CFU/g in a fermenting vegetable, which translates into 0.001% of the gut microbiota.
 - *Lb. rhamnosus*, *Lb. ruminis*, *Lb. delbrueckii*, *Lb. plantarum*, *Lb. casei* and *Lb. acidophilus* are among the 58 lactobacilli species that have been found in human feces at densities fluctuating between 6 and 8 log CFU/g (Rossi et al., 2016).

Many studies have been conducted to elucidate the mechanism by which *Lb. plantarum* could impact human health

- Several strains of *Lb. plantarum* contain genes coding for molecules and systems potentially responsible for the **stimulation of anti- or pro-inflammatory immune response in the gut** (Hemert et al., 2010).
- Strains of *Lb. plantarum* isolated from various fermented vegetables are able to **survive** in simulated gastric and intestinal conditions, adhere to intestinal Caco-2 and HT29 MTX cell tissues, **catabolize fructooligosaccharides as the only carbon source and cholesterol, and inhibit pathogens from human sources** (DeAngelis, 2017; a review).



- Lets talk.

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