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Milk microbiota: facts, open questions and roles for mother and offspring health

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Although milk has long been considered sterile, microorganisms have emerged as a natural part of this fluid. The presence of a complex microbial moiety in milk, hereafter referred to as "milk microbiota", consisting of commensal bacteria associated with healthy milk is supported by numerous studies, especially in the last decade, through the use of high-throughput sequencing approaches. Based on the growing literature on this microbial moiety, this presentation will address the question of what milk microbiota is, what is known but also the remaining questions that still need to be addressed, including the role milk microbiota plays in the mother and offspring physiology and health.

The presence of a complex microbial moiety in healthy milk is now widely accepted, at least once milk is expressed. Whether a complex and living microbial community can be associated with milk inside the breast and the mammary ducts remains to be determined. Milk microbiota is characterized by a low microbial load but a high diversity with several dozens of genera and more than 200 species identified so far. It has mainly been characterized in human and ruminants. The most frequently cited taxa include *Staphylococcus* and *Streptococcus* but also *Bifidobacterium, Corynebacterium, Propionibacterium, Bacteroides, Enterococcus, Faecalibacterium, Lactobacillus, Veillonella, Serratia, Ralstonia, Acinetobacter, Rothia* and several members of the Lachnospiraceae and Ruminococcaceae families. A cross-species analysis of milk microbiota even suggested that some of these frequently cited taxa could be universally shared within species, thus constituting an inter-species core milk microbiota (Oikonomou et al., 2020). The fungal and viral milk communities have also started to be explored. Several factors contribute to shape the milk microbiota or affect its composition, including host and environment factors as well as methodological factors, which likely introduce distortion in milk microbiota analysis.

Several questions remain on this complex microbial moiety of milk, in relation to its origin, the factors shaping its composition, its viability, and on its contribution to infant's gut microbiota establishment and health as well as mammary gland health. The origin of milk microbiota remains a matter of debate. Milk microbiota is likely a combination of microorganisms originating from mother skin and infant oral cavity as well as from maternal gut through a yet hypothetical entero-mammary pathway. Besides, discrepancies between culture-dependent and independent studies suggest that part of milk microbiota is either non-viable or non-cultivable, inviting us to a better characterization through high-throughput culture-dependent methods.

The latest findings on the role it plays in the offspring physiology and health suggest milk microbiota contribute to infant'gut microbiota shaping (Boudry et al., *in press*). Likewise, milk and mammary gland microbiota diversity and composition were shown to be related to mammary gland health. Finally, several studies support milk microbiota as a reservoir of beneficial bacteria for both infant's gut and mother's mammary gland health, inviting us to further explore this fascinating microbial community.

Oikonomou, G., Addis, M.F., Chassard, C., Nader-Macias, M.E.F., Grant, I., Delbès, C., Bogni, C.I., Le Loir, Y., and Even, S. (2020). Milk Microbiota: What Are We Exactly Talking About? Front Microbiol *11*, 60.

Boudry, G., Charton, E., Le Huërou-Luron, I., Ferret-Bernard, S., Le Gall, S., Even, S., and Blat, S. (in press). The relationship between breast milk components and the infant gut microbiota. Front Nutrition