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Effect of Feeding Methods on Modeling of Gut Microbiota of Infants

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Abstract *: There is rapid increase in the awareness of composition of microbiota in the gut and its pathogenecity and functionality.The sterile gut of the infant at birth is colonized by diverse microbiota depending upon the immediate environment.Feeding methods has an influence on the development of gut microbiota of the infants as the feeds,feeding equipment and the personnel handling the feeds form the extrinsic factors.Breast milk, being the natural feed for the infant, promotes the growth of more symbiotic bacteria and provide protection against autoimmune disorders and allergic reactions.Whereas feeding methods other than exclusive breast feeding promotes the development of microbiota which can arouse pathological effects with slight disturbances in the gut environment predisposing the infant to many illnesses which may be fatal.*

Keywords: *Infant feeding methods, gut microbiota, breast feeding, formula feeding and pathogenic effects of microbiota*

I. Introduction

Human gut is an excellent habitat for microorganisms and it is a vibrant fact that the type of the microorganism in the gut is predisposed by the dietary habits and diet. The normal infant gut at birth is sterile. The acquaintance with the environment and maternal interaction makes it a colony of bacteria. Recent research in this field indicated that the gut micro biota developed in the early years have an influence on the development of diet related non communicable diseases in the later years. Changes in the composition of gut enterotypes are found to be associated with the incidence of obesity and Inflammatory Bowel Diseases (IBD). With the changes in gut micro biota due to inf ant feeding habits the infants are susceptible to infectobesity (Di Baise *et al*.2008).Studies conducted by Mercides de Onis *et al*. (2010) indicated that there is a very high prevalence of childhood obesity globally.In KSA, even though breast feeding is considered as an important and natural feeding method for infants, mothers adopt different methods of infant feeding (Daifellah *et al* 2014). Exclusive breast feeding for 6 months after birth is recommended by WHO (Kramer and Kakuma., 2012; James and Lessen,2009). Taking into consideration of the nutritional adequacy and immunological advantages continuation of breast feeding for two years or longer is suggested (WHO,2007and WHO, 2008).Infant feeding practices were categorized by WHO as, exclusive breast feeding or breast feeding alone, predominant breast feeding and any breast feeding(Wu *et al*., 2011).

The current review attempts to provide a summary of mechanisms by which different feeding methods influence the development of enterotypes in infants' gut.

II. Diversity of human gut micro biota

Soon after the delivery sterile intestinal tract of the infants starts to harbor millions of microorganisms. Positive redox potential of the intestinal milieu of neonates at birth encourages colonization of facultative anaerobes such as Enterobacteriaceae, Lactobacillus etc. Later the colonization of obligatory anaerobes such as Bifidobacterium, Bacteroides, Clostridium etc occur due to the consumption of oxygen by facultative anaerobes (Penders *et al*., 2006).

A high diversity is the key factor of a micro biota in healthy individuals. Arumugham *et al* (2011) defined microbiota with similarities in high level organization as enterotypes. Dietary patterns influence the type of enterotypes in the gut. There are three major types of enterotypes viz., Bacteroides, prevotella and ruminococcus enterotypes which were associated respectively with animal fat /protein and carbohydrate based dietary patterns. The basis for enterotypes clustering is unknown and it appears independent of nationality, sex, and age or body mass index.

2.1.Bacteroides

Bacteroides is a genus of gram negative bacteria. The major bacteroid found in gut is Bacteroides thetaiotaomicron which are rod shaped, anaerobic, and non-spore forming bacteria. They can be isolated from

fecal matter (Xu *et al*.,2003a). It has contributed to postnatal gut development (Xu *et al*.,2003b).However, it is also a key gram-negative bacterial pathogen with extreme disease causing potential as well as antibiotic resistance.

The anaerobic bacteroides had a major role in the fermentation of carbohydrates, biotransformation of bile acids and other steroids and utilization of nitrogenous substances from the colon. Through anaerobic respiration they produce acetic acid, isovaleric acid, and succinic acid.

Xu *et al*(2003b) found the saccharolytic effect of intestinal bacteria and observed that the intestinal bacteria ferments carbohydrates in to Short Chain Fatty Acids(SCFA) leading to the production of acetic acid, propionic acid and butyric acid(Gibsen and Glen,2004). The SCFA produced were utilized as energy sources. However, about 2% of simple sugars were fermented by the Bacteroides and thus, the main source of energy for bacteroides are the unavailable carbohydrates from the plant fibres and vegetable starches. These include cellulose, arabinogalactan, pectin, xylan, and vegetable starches such as amylose and amylopectin.

2.2. Prevotella

Prevotella is the genus of gram negative bacteria. Arumugham *et al.* (2011) found that the enterotypes prevotella is related to carbohydrates and simple sugars, indicating an association with feeds based on carbohydrates, while Bacteroides enterotypes are associated with animal proteins, amino acids and saturated fats which are the typical components of a formula feed. Wu *et al.*(2011)indicated that the development and dominance of one enterotype over the other depends on the components of infant feed. The infants who are on feeds rich in protein and animal fats develop Bacteroides bacteria, whereas Prevotella species dominate for those who consume breast milk which is high in carbohydrates (Wu *et al*.,2011).

2.3. Ruminococcus

Ruminococcus is a Gram-positive anaerobic bacterium, belonging to the Firmicutes division (Ludwig *et al*.,2009). Colonization by R. gnavus was found in infants during the first days of life (Favier *et al*., 2003 and Joossens *et al*.,2011) pointed that R. gnavus had an important role in modulating gut inflammatory response at the mucosal surface.

The homeostatic micro biota in the gut can change to heterostatic one due to the changes in the gut ecosystem such as changes in diet, sensitivity to infections or the use of antibiotics (de Vos and Nieuwdorp, 2013).

III. Feeding habits and development of gut microbiota of infants

Infancy is a period of sudden environmental change from sterile intrauterine condition to heterogeneous microbial exposure from the immediate environment such as mother's body, the feed and the feeding equipment. Le Huerou *et al.* (2010) indicated that feeding practices influence the development of gut micro biota composition of infants directly by providing the substrates for bacterial propagation and function. WHO (2008) classified the infant feeding practices as exclusive breast feeding, predominant breast feeding, complementary feeding and bottle feeding as detailed in Table 1.

Table 1. Different infant feeding practices as per WHO (2008)

Name	Description	Allows the infant to receive	Does not allow the infant to receive
Exclusive breast feeding	Allows infant to receive breast milk only	ORS, drops, syrups	Anything else
Predominant breast feeding	Breast milk as major source of nutrients	Liquids (like water, water based drinks, fruit juice), Ritual fluids and ORS, vitamin and medicine syrups	Anything else particularly animal milk, fluids based on food
Complementary feeding	Allows the infant to receive breast milk (including milk expressed or from a wet nurse) with any foods or liquid including non-human milk or formula.	Anything else	NA
Bottle feeding	Any liquid including breast milk or semi-solid food from a bottle with nipple or teat	Anything else	NA

Microbial colonization in the gut of infants is influenced by extrinsic as well as intrinsic factors. The feeds as well as the feeding equipment and the immediate surroundings under which the feed were prepared and served or the feeding practices form the extrinsic factors. Various effects of different feeding habits on the proliferation of different species of microorganisms are given in Table 2.

Harmsen *et al.* (2000) observed that there were variations between the gut microflora of infants following different feeding methods. It was also noticed that bifido bacterial species along with bacteroids and enterobacteria were the dominating micro flora in the gut of infants on exclusive breast feeding.

Growth of bifido bacreria are often taken as useful indicator of human health under most environmental conditions, based upon the fact that they play important roles in metabolism of amino acids and vitamin production (Hoover, 1993).They also provide immunity (Hentger,1983) and are associated with longevity, antitumor activity(Hughes and Hoover,1991,Hoover,1993) and immune potentiation (Perdigen *et al.*,1995).The specific immunological and nutrient composition of breast milk enhances the growth of bifido bacteria in the intestine.

A surveillance of infant feeding practices (Mohammed *et al*., 2004) indicated that exclusive breast feeding was low in many parts of the world. Mohammed *et al.* (2004) observed that exclusive breast feeding and the mucosal microflora acquired in early infancy protect the infant against autoimmune syndromes such as eczema and atopic allergy (Ogra and Welliver., 2008).Immanuel (1995) commented that 63.2 per cent of the patients reported in a skin clinic with atopic eczema were below two years of age and were followed feeding practices other than breast feeding due to delayed autoimmune responses to food in the digestive tract.

Table 2. Effect of feeding practice on proliferation of gut microbes

Type of feeding practice	Name of microbe	Reference	Peculiarity of gut microbe
Exclusive Breast feeding	Bifido bacteria Bifidobacterium breve B.adolescentis B.longum B.bifidum B.infantis Bacteroides and Enterobacteria	Balmer and Wharton(1989) Mackie *et al*.1999 Harmsen *et al.* 2000 Fanaro *et al.* 2003 Bezirtzoglou *et al*.2011 Fallani *et al*.2011	Stable and uniform (Bezirtzoglou *et al.* 2011)
Predominant Breast feeding	Bifido bacteria Bifidobacterium breve B.adolescentis B.longum B.bifidum and B.fragilis	Mackie *et al* 1999 Harmsen *et al* 2000 Fanaro *et al* 2003 Fallani *et al* 2011 Penders *et al* 2006	Indicate a wide microbiota spectrum
Complementary feeding	Bifido bacteria Bifidobacterium breve B.adolescentis B.longum B.bifidum and B.fragilis	Mackie *et al.* 1999 Harmsen *et al*.2000 Fanaro *et al.* 2003 Fallani *et al*.2011 Penders *et al*.2006	Indicate a wide microbiota spectrum
Bottle feeding	Clostridium sp.s Streptococcus sp.s Bacillussubtilis Bacteroides vulgatusVeillonella parvula LactobacillusacidophilusE.coli Pseudomonas aeruginosa Enterococcus faecalisAtobium	Bezirtzoglou *et al*.2011	The counts were higher than in those of breast fed infants

Predominant breast feeding with breast milk and formula milk was the most common type of feeding. Norah (2014) found that about 70 per cent of mothers either ceased predominant breast feeding or shift to complementary feeding or bottle feeding which indicate that majority of the infant's gut have high counts of Atobium ,Bacteroides vulgatus, Bacillus subtilis, Clostridium paraputrificum ,C.perfringens, C.clostridiiforme, C.difficile, C.tertium, E.coli, Enterococcus faecalis , Lactobacillus acidophilus, Pseudomonas aeruginosa, Streptococcus bovis, S.faecalis, S.faecium and Veillonella parvula.

The intestinal micro biota in healthy subjects remains relatively constant but is known to be significantly influenced by physical, chemical and environmental host factors. Alterations to the micro biota may cause abnormal physical conditions or diseases.

Table 3 indicates various effects of microbes found in the gut of infants following feeding practices other than exclusive breast feeding.

Table 3. Pathogenic effects of microbes found in the gut of infants following feeding practices other than exclusive breast feeding

Sl.No.	Name of bacteria	Pathogenic effects	Reference
1.	Atopobium group	Acute retropharyngeal abscess	Kageyama *et al.*1999
2.	Bacillus subtilis	Non-pathogenic	Oggioni *et al.*1998
3.	Clostridium sp.s	Gaseous gangrene Necrotizing enterocolitis GI tract disorders Food toxicitySudden death	De La Cochetière *et al.*2004
4.	Streptococcus bovis S.faecalis S.faecium	Endocarditis, Colorectal cancer , Neonatal septicemia and meningitis Infections in immune deficient infants. Bacteremia and meningitis	Gerber *et al* .2006 Ryan and Ray., 2004 White *et al*.2002 Shugui *et al*.2008 Coudron *et al*. 1984
5.	Bacteroides vulgatus	Celiac disease	Ester *et al.* 2014 Federica and Guglielmo., 2012
6.	Veillonella parvula	Not considered as a pathogen	Yoshimi *et al.*1984
7.	Lactobacillus acidophilus	Allergic reactions	Yoshimi *et al.*1984
8.	E.coli	Gastroenteritis, Urinary tract infections and neonatal meningitis	Yoshimi *et al.*1984
9.	Pseudomonas aeruginosa	Urinary tract infections, Respiratory system infections, dermatitis, soft tissue infections, bacteremia, bone and joint infection and GI tract infection.	Yoshimi *et al*. 1984 Balcht and Smith.,2005

The major microbes developed in the gut of infants following feeding practices other than breast feeding may produce pathogenic effect on the infant. The main morbific effects observed were allergic reactions, celiac disease, bacteremia, colorectal cancer, endocarditis, food toxicity, gaseous gangrenes, GI tract disorders, gastro enteritis, infections in immune deficient infants, necrotizing enterocolitis septicemia and sudden death. However, Ivarsson *et al.* (2002) found that the gut microflora developed due to breast feeding had a protective effect against disease development.

IV. Conclusions

The sterile neonate's gut soon after birth colonizes with diverse microbiota due to the contact with maternal and immediate environment. The mode of feeding the infant affect the development of microbiota within the gut of the infant and many studies indicated that there is difference in the colonization of microbes in the gut of infants on different feeding methods. The feeds, feeding equipment and the personnel who handle the feeds form the extrinsic factors which affect the development of microbes. In breast fed infants, the microbiota is less diverse and nonpathogenic.

The protective action of breast milk seems to rely not only on its specific immune giving components but also on its ability to modulate intestinal microflora composition at primary periods of life. Recently, milk formulae with prebiotics, probiotics, and lacto transferrin have been established to change newborns' microflora composition toward breast-feeding pattern and stimulate immune response. The current review stress the fact that beneficial health-effects of breast milk are indisputably exceptional, has to be natural food of choice for infants in the first 6 months of life. Hence breast feeding should be encouraged and new researches are called for to find specific interactions amongst diet, microbiota composition and health of infants.

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