Quandary of Enterococci - their beneficial and detrimental roles in food, environment and medicine

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Review Article

Abstract

Enterococci are lactic acid bacteria that are widespread in nature; they were initially grouped with the genus *Streptococcus*. *Enterococcus* species are Gram-positive cocci bacteria that have their applications in food, environment and health care. The presence of *Enterococcus faecalis*, in water for instance indicates faecal contamination and possible presence of pathogenic organisms. Oral application of probiotic enterococci confers health advantages while antihypertensive effect and amelioration of influenza infection by *E. faecalis* upon oral administration are beneficial to health. Improvement of intestinal ecosystem disturbed by antibiotic usage has been recorded. However, enterococci have ability to easily possess, amass and distribute genes that code for antibiotic resistance and pathogenic factors. They equally possess virulence factors among which are ability to hydrolyse gelatin, casein, haemoglobin and other bioactive peptides. They also cause agglutination and lyses of erythrocytes. The formation of biofilm on both biotic and abiotic surfaces is a universal survival strategy of enterococci. These organisms also induce the localization of cholesterol to phagosomes and also delay fusion upon infection. These *negative* attributes enable the organisms to acquire the potential to cause and inflict measurable harms in human. Furthermore, enterococci are intrinsically resistant to many antibiotics and possess ability to acquire and disseminate antibiotic resistance. They are of particular medical relevance because of their implication in both community- and hospital-acquired infections which could be transmitted through many sources. Therefore, man is still in a dilemma over the use of enterococci in food and other related industries owing to their ever increasing medical implications.

Key words: Antibiotic resistance, enterococci, food safety, infections, lactic acid bacteria, probiotic.

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Dilemme des entérocoques - leurs bénéfiques et nuisibles rôles dans l'alimentation, de l'environnement et de la médecine

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Révision Article

Résumé

Enterococci sont bactéries de l'acide lactique qui sont répandues dans la nature; ils ont d'abord été regroupés avec le genre *Streptococcus*. *Enterococcus* espèces sont Gram positif coccidies les bactéries qui ont leurs applications dans les domaines de l'alimentation, l'environnement et les soins de santé. La présence d'Enterococcus *faecalis*, dans l'eau par exemple indique la contamination fécale et possible présence d'organismes pathogènes. Demande orale d' entérocoques probiotiques confère la santé avantages tout en effet antihypertenseur et amélioration de l'infection par *E. Faecalis* après administration orale sont bénéfiques pour la santé. Amélioration de l'écosystème intestinal perturbé par utilisation des antibiotiques a été enregistré. Toutefois, enterococci ont la capacité de facilement posséder, amasser et distribuer les gènes que le code de la résistance aux antibiotiques et facteurs pathogènes. Ils possèdent également leur virulence facteurs parmi lesquels sont capables d'hydrolyser la gélatine, caséine, hémoglobine et autres peptides bioactifs. Ils sont aussi la cause et agglutination lyses des érythrocytes. La formation de biofilm sur biotiques et abiotiques surfaces est un universel stratégie de survie des entérocoques. Ces organismes pourraient également inciter la localisation du cholestérol les phagosomes et aussi retarder fusion en cas d'infection. Ces *attributs négatifs* permettent aux organismes d'acquérir le potentiel de causer et infliger harms mesurables dans l'homme. En outre, enterococci sont intrinsèquement résistantes à de nombreux antibiotiques et posséder capacité à acquérir et diffuser résistance aux antibiotiques. Ils sont d'une pertinence médicale en raison de leur implication dans la communauté- et des infections nosocomiales qui pourrait être transmise par de nombreuses sources. Par conséquent, l'homme est toujours dans un dilemme à propos de l'utilisation des antibiotiques dans les aliments et d'autres industries connexes en raison de leur nombre de plus en plus implications médicales.

Mots clés: résistance aux antibiotiques, aux entérocoques, de la sécurité alimentaire, les infections, bactéries de l'acide lactique, probiotique.

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Introduction

Enterococci are members of lactic acid bacteria (LAB), that naturally inahabit the gastro-intestinal flora, oral cavity and vaginal of humans. They are widespread in nature and have been detected in the faecal microbiota of human, lower vertebrates (mammals, reptiles, birds and fish) and insects (1-3). The organisms are also associated with food products from milk and meat. Enterococci have been isolated from environmental sources such as wastes (liquid and solid), surface water and plant environments. Like those of the genera *Streptococcus* and *Lactococcus*, enterococci are Gram-positive, non-spore-forming, catalase-negative, oxidase-negative, facultative anaerobic cocci that occur singly, in pairs, or in chains. The genus was initially grouped as *Streptococcus* and later assigned to the Group D of Lancefield popular streptococcal classification. As a result of extensive molecular studies using DNA-DNA, RNA-RNA, DNA-rRNA hybridizations and 16S rRNA sequencing, members of Group D *Streptococcus* were assigned a genus status (4).

There are presently 37 species of the genus *Enterococcus* that have been identified currently; these include: *E. aquimarinus, E. asini, E. avium, E. caccae, E. canintestini*, *E. canintestini*, *E. canis*, *E. casseliflavusa, E. cecorum*, *E. columbae*, *E. dispar, E. durans*, *E. faecalis*, *E. faecium, E. flavescensa, E. gallinarium*, *E. gilvus*, *E. haemoperoxidus*, *E. hermanniensis*, *E. hirae, E. italicus, E. malodoratus*, *E. moraviensis*, *E. mundtii, E. pallens*, *E. phoeniculicola*, *E. porcinusb*, *E. pseudoavium, E. raffinosus, E. ratti, E. saccharolyticus, E. saccharominimus*, *E. seriolicida, E. silesiacus*, *E. sulfureus, E. termitis* and *E. villorumb (*5).

Applications of enterococci in environment, food, and medical industries

Enterococci as indicator organisms

Indicator organisms are normally associated with the intestinal tract of warm-blooded animals, and are used for indicating faecal contamination of water and possible presence of pathogenic organisms. An ideal indicator organism should have the following attributes (i) an easy testing procedure, (ii) be of human or animal origin, (iii) posess ability to survive as long as, or longer, than pathogens, (iv) be present at densities related to the severity of faecal contamination, (v) be a *surrogate* for many different pathogens and (vi) be useful in fresh and saline waters (6-8).

Enterococcus faecalis and *E. faecium* as indicator organisms are the most human specific. They differ from the other indicator organisms by their ability to grow at pH 9.6, at both 10 °C and 45 °C and in the presence of 6.5% sodium chloride. Hence, they are used to monitor the sanitary level of both marine and fresh water body. Their ability to tolerate most harsh aquatic environment makes them better suitable candidates than *E. coli*. The life span of enterococci is longer than that of coliforms (9,10) and may be equivalent to that of viruses (11) but without multiplying (12).

Enterococci in food

The enterococci may be added to food intentionally, as fermenting organisms (starter culture) and on the other hand find their ways into the food accidentally (contaminants). In either case they influence the outcome of the ecological relationship.

Enterococci as probiotics

Probiotics are a mono- or mixed culture of live microorganisms which, when consumed by animal or man, beneficially affect the host by improving the properties of the indigenous flora. Probiote generally confers health advantages on a host upon oral consumption and help in inhibiting and or suppressing pathogenic bacteria, strengthening of the gut mucosal barrier, carrying out antimutagenic and anticarcinogenic activities, stimulating the immune system and lowering of blood cholesterol levels among other functions (13,14). Figure 1 and Table 1 succinctly summarize the attributes and uses of most known and common probiotes.

Despite the fact that foods containing enterococci have a long history of safe use, these organisms are still not considered as *generally*

recognized as safe (GRAS). Some enterococci are useful probiotics (16,17), and contribute to flavour and aroma of food products (*18).* The resistance of enterococci to pasteurization temperature, and their adaptability to different substrates and growth conditions such as low and high temperatures, extreme pH, and salinity, implies that they can be found either in food products, manufactured from raw materials (milk or meat) and in heat-treated food products. This means that these bacteria could withstand usual/normal conditions of food production. In addition, they can contaminate finished products during processing and survive the stage of processing. Therefore, enterococci can become an important part of the fermented food microbiota, especially in fermented cheeses and meat products. The finding of Hayakawa *et al*. (19) however, suggests the presence of a non-hospital pool of vancomycin-resistant (VR) *E. faecalis*, which is of a great concern.

Enterococci in cheese production

It is common knowledge that enterococci are normal inhabitants of the gut flora of humans and animals; this thereby provides a rationale for their use as a component of functional foods. Cheese is a fermented product usually from the milk of ewe, goat, cow and buffalo by probiotic organisms. Enterococci are major organisms that positively affect taste, colour and the sensory profile of full-ripened cheeses in all the production stages. They are often part of the natural microflora involved in flavour and texture development during fermentation of certain foods such as cheese and cured meats. Enterococci generally have good sensory properties, resistance to phages, viable during processing and stable in the product and during storage (16-18,20,21).

Meat fermentation

Reports indicate that enterococci play important roles in the natural preservation of meat products (pig, chicken, beef, poultry, and mutton) by controlling the growth of some spoilage bacteria and pathogens. Bio-protection of meat products is achieved by the application of bacteriocin-producing LAB for their *in situ* bacteriocin production or by the direct addition of bacteriocin from the culture supernatant of the bacteriocin-producing strains (22). During meat fermentation, pathogenic, spoilage and protective bacteria may be present. Fast growth of highly competitive starter cultures or endogenous LAB by comporting acidification, decrease redox potential and water activity hence make the environment highly unfavourable for both the pathogenic and spoilage organisms. Enterococci and *E. faecalis* in particular, are known to be highly competitive in their environments and are useful for this particular purpose.

Enterocin production for the control of pathogenic and spoilage organisms

The bacteriocins produced by enterococci belong to the large group of small, cationic, amphiphilic, antimicrobial peptides synthesized in the ribosomes. Their activity, molecular property, and mechanisms of action differ generally. Their physicochemical attributes; thermostability, pH range of activity, and genetic determinants also vary (3, 23,24).

The bacteriocin of enterococci called enterocin is a class of bacteriocins produced by *Enterococcus* species. Enterocins are small and heat-stable; its production is an important characteristic of most *Enterococcus* spp. Enterocinogenic strains have been isolated from different sources including sous-vide cooked fish fillets (25), Italian ryegrass (26), intestinal track of ostrich (27,18) and chicken caeca (29). Enterocins are grouped in the current bacteriocin classification systems. Antibacterial potencies of the enterocins have been tested on both Gram-positive and Gram-negative bacteria of medical importance with very promising outcomes (3, 29, 30, 31).

The antimicrobial activities of enterocin are directed against a broader spectrum of bacteria than is seen for other bacteriocins produced by Gram-negative bacteria (28). These bacteriocins are effective on broad-spectrum of bacteria; hence are good candidates for bio-preservation of foods for which they have found useful application in the food industry.

Application of enterococci in the management of health-related conditions

The health benefits of LAB and enterococci as probiotics have been aptly reported. Probiotics normally function as colonizers and contribute positively to the overall health of their hosts by multiple mechanisms in communicable infections and or diseases. These include but not limited to modification of flora, gut barrier integrity maintenance, local release of antimicrobial factors, competition for epithelial adherence, inhibition of pathogen movement from the gut to the other tissues and organs, immunomodulation and prevention of allergic disorders (32-37).

Probiotics and or probiotes have found some useful applications in the management of non-communicable diseases as well. For instance, hypertension is a non-communicable controllable risk factor for development of cardiovascular diseases (38). Synthetic antihypertensive drugs are commonly used to treat and manage hypertension. However, some side effects have been associated with this intervention, hence the need for safer, natural compounds and effective means of management (39, 40). Enterococci serve as reliable alternatives as indicated by Shimada *et al*. (41) who reported the antihypertensive effect of heat-killed *E. faecalis* FK-23 cells upon oral administration**.** The authors observed a significant reduction of high systolic blood pressure following oral administration of a strain of *E. faecalis* FK-23 preparation for 7 days in animal models. Long term administration of the preparation for 270 days reportedly reduced systolic blood pressure with negligible effect on the accompanying myocardial hypertrophy (41, 42). This finding no doubt confirms the presence of some compounds from the heat-killed extract of *E. faecalis* FK-23 responsible for the reduction of systolic blood pressure. The benefit of milk and dairy products involving LAB in the management of gastric ulcer is common knowledge.

Application of enterococci in ameliorating influenza

According to reports, *E. faecalis* affects alveolar-capillary permeability to attenuate leukocyte influx in the lung following infection by influenza virus. Influenza A virus is known to be one of the most dreaded common life-threatening viruses, and causes accumulation of inflammatory cells in the lungs, which directly correlates with influenza-associated morbidity and mortality (43-45). In virus-infected mice, Fukada *et al*. (46) investigated the potential of lysozyme-treated *E. faecalis* strain to prevent influenza infection and observed modulation of pulmonary alveolar-capillary permeability. The findings established the stabilization of the integrity of the alveolar-capillary barrier while also administration of the test organism improves survival rate.

Enterococci in control of atopic reactions

Use of antibiotics at early stage of life has epidemiologically been linked with allergy and occurrence of hypersensitivity reactions including asthma (47-51). Administration of *E. faecalis* improves the intestinal ecosystem previously disturbed by antibiotic use, and thereby prevents subsequent development of atopy. *Shimada et al*. (52) reported that lysed cells of *E. faecalis* strain had inhibitory effects on allergen-induced immune responses. It was further observed that the ratio of serum total immunoglobulin E to immunoglobulin G levels was significantly increased in erythromycin-treated mice relative to that found either in lysed *E. faecalis*-treated mice or in erythromycin-treated mice with lysed *E. faecalis* supplementation while the treatment with lysed *E. faecalis* did not interfere with the gut microbiota.

Enterococci as natural immune enhancers

The gut microbiota plays an active and very significant role in several physiological functions of the host. Oral administration of LAB probiotics has been reported to modulate both innate and acquired immunity at the local as well as systemic levels in humans (34, 53-55). An adjuvant effect of enterococci at both mucosal and systemic levels reportedly improves the protective immune responses against various infections through the production of an antibody (34, 56-58).

Thus far, the benefits of this group of organisms

have been summarized. This may sometime seem unbelievable or too good to be to comprehend, since microbes are generally perceived as the greatest eniemies of mankind. Having allayed most of the fears about microbes, and in our case *Enteroroccus*, it is also most appropriate to state briefly that all are not that rosy with these organisms. Just like a coin which has its other side, the dilemma man faces with these unarguably very useful bacteria needs as well be narrated briefly to caution against, do we say, abuse or to bring to the fore, the need to be careful in the day-to-day handling of some of these organisms which abound in and around us.

Enterococci and diseases

Although enterococci have been described to have several valuable applications in food production and preservation, with obvious uses in many areas of human health management as well, however, possession of several other *negative* attributes turns the odds against the organisms as many species are important opportunistic and nosocomial pathogens of humans (59-62).

In the past decades, enterococci have emerged as important pathogens and continue to attract considerable attention globally (21, 63, 64*)* owing primarily to the high degree of antibiotic resistance exhibited by most clinical enterococcal isolates particularly VR strains of *E. faecalis*. Hammerum *et al.* (65) reported rapid spread of vancomycin resistance among *E. faecalis* and this is of grave public health concern. Enterococci are important human pathogens frequently implicated in human infections and *E. faecalis* and *E. faecium* have been linked with most infections in community, long-term care and hospital settings (66-68).

Enterococci are intrinsically resistant to many antimicrobial agents, including cephalosporins, clindamycin, and penicillinase-resistant penicilins (69). They have low-level intrinsic resistance to aminoglycosides. Piperacillin and the carbapenems were reported to show a good activity against enterococci but had no advantage over ampicillin. Plasmid-mediated ß-lactamase production by some strains of *E. faecium* reportedly led to further problems with treatment of serious enterococcal infections (70). In addition to vancomycin and high-level aminoglycoside resistance, most strains of VRE also have chromosomally-mediated resistance to the penicillins. The number of antibiotic-resistant enterococci, especially VRE, is increasing unabated (70, 71) which is a great public health issue as this may lead to treatment failures and increased hospital costs with other attendant consequencies.

Pathogenic factors

Enterococci have natural ability to acquire, accumulate, and share genetic elements encoding virulence traits which are responsible for their ability to cause infections and or diseases, and antibiotic resistance (72). They are frequently responsible for causing a variety of human infections. Several virulence factors have been identified in enterococci which among others include haemolysin, aggregation substance (Agg), cytlosin (cyl), enterococcal surface protein (Esp), gelatinase and serine protease (1, 3, 30, 73-79).

Agglutination

Agglutination of erythrocytes by bacteria is a convenient measure of adherence. It contributes to attachment to host cells (80, 81), and was identified to be caused by thermostable compounds of proteineous and non-proteineous nature. Haemagglutination-positive *E. faecalis* isolates have been shown to produce identical results with all kinds of erythrocytes, suggesting that binding was unspecific or caused by the presence of different adhesins (82).

Aggregation substance

Aggregation substance (*Agg*) is a pheromone-inducible surface protein of enterococci, which promotes aggregate formation during bacterial conjugation (69, 83). It mediates efficient enterococcal donor-recipient contact to facilitate plasmid transfer and thus contributes to the pathogenesis by influencing phagocytosis and subsequent damage of the vital functions of the organism. Furthermore, it increases the hydrophobicity of the enterococcal surface, which helps induce localization of cholesterol to phagosomes, and also prevents or delays fusion (84-86).

Haemolysin
Haemolysin is one of the virulence factors associated with enterococci; it is considered to be important as it enhances the severity of haemolytic activity and ability of the organism (30, 87). Cytolysin production is associated with better ability to reach the blood stream and induce septicaemia resulting in a fivefold increased risk of acutely terminal outcome in patients (30, 88). Other enterococcal pathogenic or virulence factors are adhesion, hyaluronidase and lipolysis.

Enterococcal extracellular surface protein
Extracellular surface protein plays a role in adhesion and evasion of the immune response of the host (86). It also plays a role in biofilm formation and adherence to abiotic surfaces. Biofilm is an irreversible three dimensional, sophisticated architecture that plays an active role in human infections (89-91). *In vitro* susceptibility tests have shown considerable increase in resistance of biofilm cells to killing. Biofilm formation (Fig. 2) is a universal strategy for bacterial survival which positions the bacteria to effectively use the available nutrients (92, 93); a survival strategy employed mostly to colonise, survive and thrive in new ecological niches. Furthermore, biofilm formation is a major contributor to the pathogenesis of enterococcal infection and has been suggested to enhance horizontal transfer of genetic traits (21, 94, 95, 96).

Gelatinase
Gelatinase is an extracellular zinc metallo-endopeptidase secreted by enterococci (98). This enzyme has the ability to hydrolyse gelatin, casein, haemoglobin and other bioactive peptides. The gene encoding its production is located on the chromosome and regulated in a cell-density-dependent manner (99). Aside from some functions in biofilm formation, gelatinase plays a major role in enterococcal pathogenesis by making nutrients available to the organism through degradation of host tissues (84, 93). Gelatinase has been associated with virulence determinant in animal models. Its ability to hydrolyse gelatin, collagen and certain bioactive peptides is an indication of its participation in the initiation and propagation of inflammatory processes in infections that involve gelatinase-producing organism such as *E. faecalis* in various human infections and or diseases including dental infections (31, 78, 100, 101).

Sex pheromone
Enterococcus species communicate among themselves with the aid of sex pheromones for the exchange of genetic materials. Plasmid-deficient strains may induce a mating response with plasmid-harbuoring bacteria within or outside the genus (102). In response to the pheromone produced, the recipients produce substance that facilitates mating aggregates (103). After mating, the activity of the pheromone can no longer be detected in the medium. The endogenous pheromone is either masked or the cells are desensitized. Enterococcal sex pheromone is unique in the sense that the response to mating is triggered by recipient after which the plasmid DNA transfer is initiated. Some attributes such as antibiotic resistance, virulence and bacteriocin production of enterococci have been linked with the possession of plasmids (104, 105).

Enterococci as nosocomial pathogens
The most controversial species of LAB found in food products are the enterococci. As previously stated, they are found in the normal intestinal flora of most healthy adults. Enterococci are poorly pathogenic and frequently cause colonization rather than invasive infection hence the need to assess each patient to distinguish between colonization and infection. They have taken a prominent position among the most common pathogen isolated from hospitalized patients (21, 30, 106). Environmental contamination with enterococci in the hospital setting has been reported and bedside rails, urinals and bedpans are commonly described as potential sources of microbial transmission (107).

Antibiotic resistance in enterococci
The incidence of nosocomial or hospital-acquired infections has not only dramatically increased but also the therapeutic failures due to increasing antimicrobial-resistant of *Enterococcus spp. (*108, 109).
Enterococcal resistance to the following

antibiotics has been reported: cephalosporins, beta-lactams, sulphonamides,clindamycin, aminoglycosides, chloramphenicol, erythromycin,tetracycline, fluoroquinolones, glycopeptides, vancomycin and linezolid (Table 2). Vehicle for transmission of VRE has been identified to include but not limited to bedrails, counters, sinks, toilet, stethoscope, blood pressure cuff, bedpans, electric thermometers, scale, bed sheets, door knobs, air conditioning, different types of telephones, Automated Teller Machines, an apron (32, 110, 111). This in addition to their unimaginable intrinsic capability to adapt to any ecological environment creates serious epidemiological concern and challenge to medical practice (Table 2).

Enterococci are poorly pathogenic and frequently cause colonization rather than invasive infection. The need therefore arises in the healthcare setting to distinguish between colonization and infection through assessment for decision-making on whether antimicrobial therapy and/or other interventions are necessary.

Like in other bacteria, transfer of genes in enterococci may either be from parent cells to their offspring (vertical transfer) or by the process in which an organism takes up genetic material from an entirely different organism and not necessarily an offspring of that particular (donor) organism (horizontal gene transfer). Horizontal gene transfer probably has a great impact on the evolution and genome plasticity of enterococci. Enterococci can acquire and transfer gene to a related species and also across major taxonomic bacterial divisions. The genetic information may be transferred intercellularly in three major ways; transduction, transformation and conjugation (112-114), as depicted graphically in Fig. 3. Other mechanisms of antimicrobial resistance may be in other forms such as modification of antibiotics by the enzymes produced by enterococci, alteration of target sites like DNA gyrase, utilization of alternates to pathways that have been, creation of barriers to prevent penetration into the cell and efflux pumps that exclude the anti-enterococcal agent from the cytoplasm (115).

Enterococcal infection

Like most communicable bacterial infections, enterococcal infections have the following stages: colonisation/adherence, translocation, evasion of the immune response and induction of pathological outcome or changes. Typical enterococci are examples of organisms linked with iatrogenic infections which may be a source of bacteraemia, bloodstream infections or sepsis and leading to other complications typical oocupational harzads.

Manifestations of enterococcal infections

Enterococcal infections can be manifested in several ways including the under-listed;
i. Bacteraemia, ii. Bloodstream infection, iii. Gastrointestinal infection, iv. Genitourinary infection, v. Endovascular infections, vi. Endocarditis, vii. Urinary tract and other infections, viii. Sepsis, ix. Intraabdominal infections, and x. Pelvic infections (116).

Underlying factors for enterococcal infections

Listed below are some major factors which may predispose to enterococcal infections as may apply to many other communicable infections and or diseases:

1. Length of hospital stay,
2. Proximity to a hospitalized patient with VRE colonization or infection,
3. Care by a nurse who is also caring for a patient with VRE colonization
4. Severity of illness risk factors such as renal failure, recent surgery, hepatobiliary disease, immunosuppression, and organ recipient status
5. Antimicrobial risk factors including prior exposure to antibiotics like vancomycin, ceftazidime, ciprofloxacin, metronidazole,
6. Number and duration of recent antibiotics treatment
7. Diabetes mellitus
8. Renal diseases
9. Cerebral vascular accident
10. Congestive heart failure
11. Chronic obstructive pulmonary disease
12. Dementia

13. Recent hospitalization
14. Use of narcotic/antiperistaltic agent
15. Surgery in previous 2 months
16. Tube feeding
17. Total parenteral nutrition
18. Nothing by mouth status
19. Nasogastric/percutaneous endoscopic gastostomy tube
20. HIV, and
21. Previous antibiotic treatment and or exposure

Conclusion

There are salient points to consider during application of enterococci for either food or health promoting instances. Although the organisms are mostly of human origin, yet they are responsible for quite a number of diseases of human. They are linked with gastrointestinal tracts of both healthy and sick human. Enterococci have a history of being pathogenic and of association with various diseases such as infective endocarditis or gastrointestinal disorders. They easily deconjugate bile salts the product of which results in a negative trait in the small bowel and finally, they carry transmissible antibiotic resistance genes. The choice of these organisms as fermenters and probiotes poses potential threats to human and other animals alike considering the role of the organisms as major causes of various infectious diseases and their propensity to adapt to and colonize any imaginable ecological niche. Moreover, they are resistant to many adverse environmental conditions and possess unimaginable ability and capability to transfer genetic materials to other organisms. However, human being ordained to be *masters* over all other creatures will always be a little step ahead and tame potentially dangerous and or dangerous microbes but useful to the benefits of mankind. The fact remains that man is obviously at a *crossroad* presently in the choice and use of some microbes for some benefits, particularly members of the genus *Enterococcus*. All these have been briefly enumerated in this review.

Conflict of Interest

The authors declare no conflict of interest.

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Table 1. Summary of probiotic properties and applications of enterococci

Properties	**Applications**
Bacteria	It effects competitive colonization
	Reduces pathogenic bacterial colonization and translocation
	Improving the properties of the indigenous flora
	Inhibition of pathogenic microorganisms
Digestion	Reduces lactose intolerance
	Strengthening of the gut mucosal barrier
Prophylactic	Decrease in the duration of diarrhoeal symptoms
	Normalization of patient's stools
	ptimulation of the immune system
	Prevents mutagenicity
	Prevention of cancer
Reduction of disease	Effects hypocholesterolaemia
	Lowering of blood cholesterol level
	Prevents enteritis
Genitourinary applications	Prevents vaginal candidiasis

Table 2: Summary of antibiotic resistance in enterococci

Antibiotic	**Mechanism of resistance**	**Origin of resistance**
ß-lactam antibiotics	Low affinity of penicillin-binding protein	Natural
Aminoglycosides	Impermeability	natural:low resistance,
	Aminoglycoside modifying enzymes,	acquired:high resistance
Macrolides	Modification target, inactivation of drugs, Efflux pump	Acquired
Fluoroquinolones	Low affinity of gyrase enzyme, efflux pump	Acquired
Tetracyclines	efflux pump	Acquired
Nitrofurantoin	Lack of nitrofuran reductase enzyme	Acquired
Teicoplanin	Low affinity to peptidoglycane	Natural
		Acquired
Vancomycin	Low affinity to peptidoglycane	Natural
		Acquired

Source: ref. 5

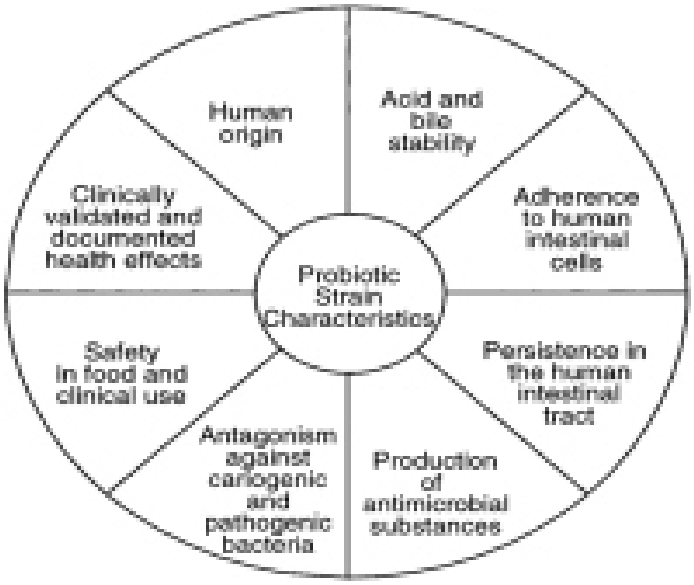


Fig: 1: Attributes of a probiotic strain (source ref. 15).

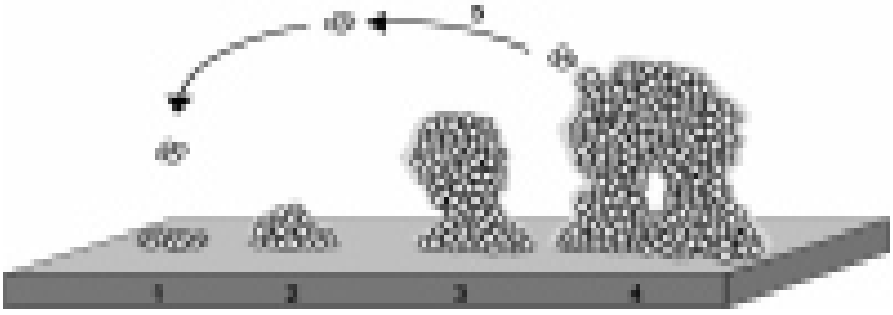
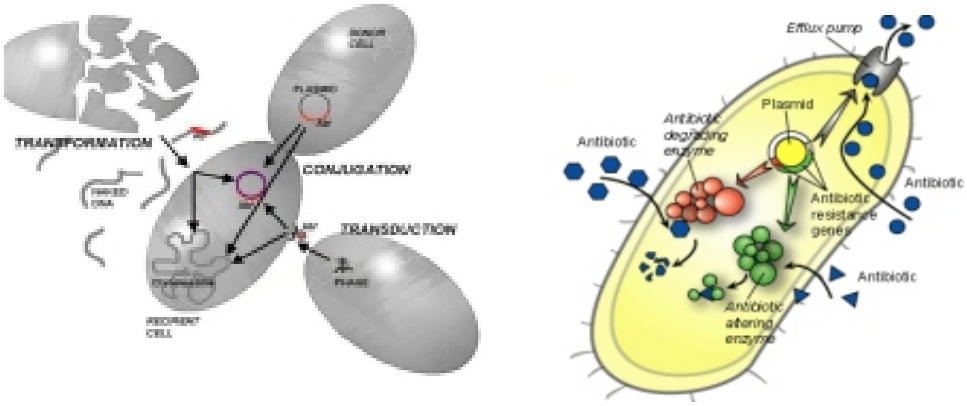


Fig. 2. The development of enterococci biofilm, depicted as a five stage process. Stage 1: initial attachment of cells to the surface; stage 2: production of the extracellular exopolysaccharide matrix; stage 3: early development of biofilm architecture; stage 4: maturation of biofilm architecture; stage 5: dispersion of bacterial cells from the biofilm (source ref. 94)



a b

Fig 3a: Acquisition of antibiotic resistance genes among enterococci. Resistance genes (Abr) can be transferred to a recipient through three mechanisms; Transformation (uptake of free, naked DNA), transduction (infection of a bacteriophage) or conjugation (plasmids, ICE) (Bjorkeng, 2010).

Fig 3b: Mechanism of resistance in enterococci