DOWNLOAD PDF IMPEDANCE MICROBIOLOGY

Chapter 1 : ESCMID: ESCMID - Home

Impedance microbiology is a microbiological technique used to measure the microbial number density (mainly bacteria but also yeasts) of a sample by monitoring the electrical parameters of the growth medium.

Uses[edit] Numerous procedures in biology and medicine require the counting of cells. By the counting of cells in a known small volume , the concentration can be mediated. Examples of the need for cell counting include: In medicine, the concentration of various blood cells , such as red blood cells and white blood cells , can give crucial information regarding the health situation of a person see: In cell therapy , to control the dose of cells administered to a patient. Similarly, the concentration of bacteria , viruses and other pathogens in the blood or in other bodily fluids can reveal information about the progress of an infectious disease and about the degree of success with which the immune system is dealing with the infection. The cell concentration needs to be known for many experiments in molecular biology, in order to adjust accordingly the amount of reagents and chemicals that are to be applied in the experiment. Studies that examine the growth rate of microorganisms in other words: Measurements of cell viability, i. Manual Cell Counting[edit] There are several methods for cell counting. Some are primitive and do not require special equipment, thus can be done in any biological laboratory , whereas others rely on sophisticated electronic appliances. Hemocytometer A counting chamber A counting chamber , also known as hemocytometer , is a microscope slide that is especially designed to enable cell counting. The hemocytometer has two gridded chambers in its middle, which are covered with a special glass slide when counting. A drop of cell culture is placed in the space between the chamber and the glass cover, filling it by capillarity. The separating distance between the chamber and the cover is predefined, thus the volume of the counted culture can be calculated and with it the concentration of cells. Cell viability can also be determined if viability dyes are added to the fluid. Their advantage is being cheap and fast; this makes them the preferred counting method in fast biological experiments in which it needs to be merely determined whether a cell culture has grown as expected. Usually the culture examined needs to be diluted, otherwise the high density of cells would make counting impossible. The need for dilution is a disadvantage, as every dilution adds inaccuracy to the measurement. Colony-forming unit A picture of Staphylococcus aureus colonies growing on an agar plate transmitted light. Such homogeneously spread colonies are suitable for CFU enumeration. To quantify the number of cells in a culture, the cells can be simply plated on a petri dish with growth medium. If the cells are efficiently distributed on the plate, it can be generally assumed that each cell will give rise to a single colony or Colony Forming Unit CFU. The colonies can then be counted, and based on the known volume of culture that was spread on the plate, the cell concentration can be calculated. As is with counting chambers, cultures usually need to be heavily diluted prior to plating; otherwise, instead of obtaining single colonies that can be counted, a so-called "lawn" will form: Additionally, plating is the slowest method of all: Although this method can be time consuming, it gives an accurate estimate of the number of viable cells because only they will be able to grow and form visible colonies. In addition, the enumeration of colonies on agar plates can be greatly facilitated by using colony counters. Automated Cell Counting[edit] Electrical resistance[edit] The electrode of a Coulter counter A Coulter counter is an appliance that can count cells as well as measure their volume. It is based on the fact that cells show great electrical resistance ; in other words, they conduct almost no electricity. In a Coulter counter the cells, swimming in a solution that conducts electricity, are sucked one by one into a tiny gap. Flanking the gap are two electrodes that conduct electricity. When no cell is in the gap, electricity flows unabated, but when a cell is sucked into the gap the current is resisted. The Coulter counter counts the number of such events and also measures the current and hence the resistance , which directly correlates to the volume of the cell trapped. A similar system is the CASY cell counting technology. Coulter and CASY counters are much cheaper than flow cytometers, and for applications that require cell numbers and sizes, such as cell-cycle research, they are the method of choice. Its advantage over the methods above is the large number of cells that can be processed in a short time, namely: This offers great accuracy and statistical significance. Flow cytometry[edit] Flow cytometry is by far the most sophisticated and expensive method for

cell counting. In a flow cytometer the cells flow in a narrow stream in front of a laser beam. The beam hits them one by one, and a light detector picks up the light that is reflected from the cells. Flow cytometers have many other abilities, such as analyzing the shape of cells and their internal and external structures, as well as measuring the amount of specific proteins and other biochemicals in the cells. Therefore, flow cytometers are rarely purchased for the sole purpose of counting cells. A range of image classification techniques can be employed for this purpose. Cells absorb and scatter the light. The higher the cell concentration, the higher the turbidity. Spectrophotometers can measure intensity of light very accurately. The cell culture is placed in a transparent cuvette and the absorption is measured relative to medium alone. Optical density OD is directly proportional to the biomass in the cell suspension in a given range that is specific to the cell type. Using spectrophotometry for measuring the turbidity of cultures is known as turbidometry. This has made spectrophotometry the methods of choice for measurements of bacterial growth and related applications. Impedance microbiology[edit] Impedance microbiology is a rapid microbiological technique used to measure the microbial concentration mainly bacteria but also yeasts of a sample by monitoring the electrical parameters of the growth medium. It is based on the fact that bacteria metabolism transforms uncharged or weakly charged compounds into highly charged compounds thus changing the growth medium electrical properties. The microbial concentration is estimated on the time required for the monitored electrical parameters to deviate from the initial baseline value. Different instruments either built in a laboratory or commercially available to measure the bacterial concentration using Impedance Microbiology are available.

Chapter 2 : American Society for Microbiology

Impedance microbiology is a rapid method that enables qualitative and quantitative tracing of microorganisms by measuring the change in the electrical conductivity.

Non-food related applications 2. Applications in the food industry 3. It was first mentioned material. The reader is referred to Eden and Eden and at a meeting of the British Medical Association at Edinburgh the more recent discourse by Kell and Davey for a in July where Stewart presented a paper later to be detailed review of impedance theory. The electrical response curves pre- system behaves either as a resistor and capacitor in series or sented followed the putrefaction of blood and serum and as a conductor and capacitor in parallel Kell and Davey were very similar to those obtained from currently available Considering the case where the system is treated as a impedance systems, the significant difference being that today series combination, then application of an alternating sinu- impedance can be considered as a rapid microbiological soidal potential will produce a resultant current which is method whereas Stewart was measuring changes in imped- dependent on the impedance 2 of the system which in turn ance over periods in excess of 30 d. However, it was not until the mid seventies that the technique began to receive the attention it merited. This coincided with the introduction of dedicated Any increase in conductance, defined as the reciprocal of impedance systems and a consequent increase in published resistance or capacitance results in a decrease of impedance work notably by Ur and Brown , , , Cady and an increase in current. T h e AC equivalent of conductance and the very important work of Eden and Torry is admittance which is defined as the reciprocal of the imped- Research Station Richards et al. T h e units of impedance measurement are Siemens S. Forsythr, Drpur,mrnr uf Lifr Scirncrs. Thr Microbial metabolism usually results in an increase in both Nutringhum Trrnr Uniocrsir. FORSYTHE concepts of impedance, admittance, conductance, capacitance defines the detection criteria and when the rate of change of and resistance are only different ways of monitoring the test impedance exceeds this pre-determined value the system will system and are all inter-related. In practical terms we need detect growth. The importance of temperature control growth kinetics of the test organism and the properties of the in any impedance system is critical, as a temperature increase test medium. At the point of tance and 1. This will vary depending on organism type and medium, but 1. It is important to differentiate between this the growth medium result directly from the changes taking detection threshold and the sensitivity of an impedance sys- place in the bulk electrolyte. It is well established that the electrode construction, organisms follow normal metabolic pathways, thus increasing stainless steel compared to platinum, will affect sensitivity of the conductivity of the test medium. Simple examples include the test system. Eden and Eden showed that electrodes the conversion of glucose from a non-ionized substrate to two located at the bottom of a test cell resulted in detection molecules of lactic acid with a corresponding increase in thresholds 1 log cycle lower than with the same electrodes conductivity. Further metabolism will take the lactic acid and located at the top of the test cell. T h e fact that real time three oxygen molecules to carbonic acid, resulting in three microbial activity is being measured rather than the activity ion pairs including the smaller more mobile bicarbonate ion, at a single point in time is a significant and powerful feature which is a more effective electrical conductor than the lactate and one which enables the system to detect the presence of ion. Hydrogen ions are nearly seven times more effective low numbers of organisms. A number of factors will affect conductors than sodium ions Eden and Eden , therefore time to detection. Firstly D T will correlate only with the one might predict that a weakly buffered medium would initial concentration of test organisms providing the gen- allow a greater impedance change than a more strongly buff- eration time of the test population is more or less constant ered one. For a more detailed appraisal of the effect of med- under the experimental conditions. Therefore not only does ium buffers on conductimetric response the reader is referred incubation temperature need to be kept constant due to to the work of Owens It is important to stress, physico-electrical properties as discussed earlier, but also however, that the principles of medium design, fundamental because it will have a direct effect on the generation time of to traditional microbiology, are equally if not more important micro-organisms. In the first instance, a medium must be chosen which will support and select for the growth of the test organism. Secondly, that medium

needs to be 1. This is well illustrated by Staphylococcus aureus which will grow in nutrient broth but High salt concentrations are routinely used in many selective does not produce a significant electrical response, whereas in media. The growth of some organisms, par- paport-Vassiliadis broth for salmonella isolation. The result- ticularly yeasts and moulds, does not result in large changes ant high impedance readings of these media are outside the in impedance. This is considered to be due in part to the fact normal working range of the direct impedance technique. Additionally, Suo- be overcome by monitoring microbial metabolism via the malainen and Oura have shown that yeasts can absorb production of CO, Owens et al. In this instance ions from solution resulting in a net decrease in medium potassium hydroxide is added to the impedance tube across conductivity. The inoculated culture medium is in a separate An impedance system can therefore be considered simply chamber and not in contact with the electrodes or potassium as measuring net changes in impedance in the culture medium hydroxide. T h e unit is tightly sealed such that any C 0 2 at regular intervals. T h e initial Easter- ance. However, subsequent salmonella strains that dioxide produced were investigated by Dezenclos et al. After injection of carbon dioxide either directly in dulcitol were reported. Hence a proposed modification of the the potassium hydroxide solution, or above the potassium medium was the replacement of dulcitol by mannitol Gibson hydroxide solution, the optimal results were obtained with ; Ogden and Cann This medium, however, still potassium hydroxide g 1 - I in a volume of 0. This agrees well with that predicted by Owens in place of dulcitol. However, using mannitol more non- - Not surprisingly the results were temperature depen- decarboxylation to cadaverine has been used to distinguish dent. Similarly Lysine-iron-cystine-neutral red technique to be a powerful tool for working with strains of LICNR broth has been used to simultaneously test for lysine Staph. False positives omonas hydrophila and Salmonella spp. Furthermore, it now due to Cit. Modified unsuitable to be used for impedance applications. Appli- levels of glucose, sodium chloride and selenite in the lysine cations of indirect impedance technology are of considerable medium were used to overcome inhibition of salmonella potential for anyone with a requirement for a rapid, easily growth due to selenite inhibition under acid conditions. Davda and Pugh 2. They were Much of the early work on impedance microbiology was in used with LICNR broth incubated conventionally in a the food and dairy industries. Firstenberg-Eden and Tricarico extended this products spiked and naturally contaminated resulted in to the determination of mesophilic and psychrotrophic counts complete agreement by rapid and conventional methods. Monitoring the total microbial loading of a wide Since bacterial reduction of trimethylamine oxide to tri- range of food products has been evaluated and shown to be methylamine is repressed under aerobic conditions it was successful for frozen vegetables Hardy et al. Surprisingly Ogden b reported that Ogden and meat products Firstenberg-Eden ; impedance changes increased and time to detection decreased Fletcher et al. Unfortunately the reason 2. This has culminated in impedance technology affected by the previous inoculum growth conditions. FORSYTHE advantage of using impedance was that large numbers of were obtained of which were obtained by the impedance experiments could be performed in comparison to time-con- method as compared to that obtained by conventional testing suming plate count enumerations. The lag phase varied and with the selenite cystine , Rappaport-Vassiliadis soya in extreme cases ranged from 16 h to 70 h. Six samples gave false-positive results Salm. The prolonged detection time noted which were due to Enterobacter cloacae. One strain each of with sub-lethally injured cells was due to an extended lag Salmonella enteritidis PT8 and Salm. The impedance method was very suitable as a screen- small, uninjured sub-population. The results indicated that ing test since negative results were obtained within 38 h. These results emphasize the need to nique with three rapid methods impedance, Gene-Trak and recover sublethally injured cells in any isolation procedure. Salmonella-Tek for the detection of salmonellae in poultry Parmar et al. Salmonellae were isolated separation to capture and concentrate salmonellae from pre- from a total of Salmonella detection was enhanced by reducing the pedance method, Additionally a reduced pre-enrichment period was all three rapid methods have AOAC approval and were proposed since salmonellae from a 6 h pre-incubation period more sensitive than the conventional procedure, the authors were detected in h by impedance. Although there was proposed that they warranted further consideration as cross-reaction with Ctt. However, the rate of false-positive contaminated with different Salmonella serotypes at two target results was high and impedance was less sensitive with pro- levels of cells in 25 g and 1 M O cells in 25 g. Each par-

cessed all animal protein samples. Subsequently they inves- ticipating laboratory tested 10 contaminated and five non-con- tigated the combined use of indirect impedance with taminated samples per product. Using Lab M medium, the indirect impedance technique could distinguish between Salmonella spp. Although other organisms grew in the medium the shape of 1 combined immunomagnetic separation with the the impedance curve could be used for differentiation between indirect RV technique to determine the levels of salmonellae Listeria and non-listeria species. Later Hancock et ul. A growth curve of Salm. Neither of these methods could distinguish pre-enrichment period and demonstrated that non-sal- between L. There is monellae out-numbered the salmonella cells by thousand- only one publication on the use of impedance microbiology to fold. The impedance medium con- sisted of magnesium chloride, malachite green oxalate, novo- Coliform organisms are frequently used as biological indictors biocin, phosphate buffer, mannitol, peptone and yeast extract. Therefore impedance is an appropriate method since impedance change in yeast cultures is the uptake of charged serial dilution of samples is often unnecessary and the results ammonium ions as the nitrogen source and the reaction of are automatically recorded. Since coliforms and E. Rhodotorula ruhra cultures is a routine technique appropriate media have been developed with L-asparagine as sole carbon source caused large increases which are suitable for impedance methods. Silverman and in impedance with growth. Chemical analysis of culture filtrates Munoz used an impedance technique to rapidly enu- showed that this increase in impedance was due to use of L- merate faecal coliforms in effluents from sewage treatment asparagine as carbon source and the excretion of nitrogen surplus plants. Martins and Selby evaluated an im- to biosynthetic requirement as ammonium. In addition, the pedance method for quantifying coliforms in meat. Similarly production of aspartate, acetate and bicarbonate contributed to a method for the detection of E. The formulation traditional plating techniques and direct and indirect imped- was based on the ability of coliform bacteria to ferment lactose ance Deak and Beuchat T h e initial populations in indicated by a change in broth colour from red to yellow and diluted 1: The presence of E. Pre-incubation demonstrated by its ability to cleave the substrate methyl- before analysis facilitated the resuscitation of cells that may umbelliferyl-P-D-glucuronide MUG to yield fluorescent have been freeze-injured. Yeasts were recovered in equal methylumbelliferone. Fluorescence was determined by exposing numbers on acidified pH 3. Yeasts the incubation period. Examination by direct impedance required possible to enumerate CI. However, an additional h to reach changes in impedance of knowledge that a sample contained clostridia allowed a count to 5 pS h-I.

Chapter 3 : Cell counting - Wikipedia

Impedance microbiology is a method that enables tracing microbial growth by measuring the change in the electrical conductivity. Different systems, able to perform this measurement, are available in commerce and are commonly used for food control analysis by mean of measuring a point of the impedance curve, defined "time of detection.".

Several authors have made use of culture conductance changes during bacterial growth for quantitative and qualitative assessments of microbial growth. However, interface capacitance curves, Ci , have not been used. In this paper, we quantify bacteria in cow raw milk by following their growth as the above-mentioned capacitance change time course event. With it, bigger growth variations, shorter detection times and a better coefficient of correlation with the plate count method were obtained than those yielded by conductance curves. Bacterial quantification; Milk contamination; Electrodeâ€"electrolyte interface; Interface capacitance; Conductance 1. Introduction Silley and Forsythe , and in the interdisciplin- ary review by Valentinuzzi et al. Electrical impedance, as a principle of transduc- From on, and to this date, very few papers tion, has been applied in a wide variety of bio- have added new basic knowledge or new ideas to the medical problems Geddes and Baker, One subject Hause et al. Some of the techniques herein described are protected by ty of the microorganisms Silley and Forsythe, the Argentine pending patent [S 98 38 C. In such the detection and estimation of yeast in fruit juices case, the impedance readings are outside the normal Deak and Beuchat, and wine Henschke and working range of the direct impedance method. This Thomas, , or to detect Escherichia coli in problem can be overcome by monitoring microbial potable water Colquhoun et al. It includes the medium were determined by plate counting, as a function of conductance Gm , the interface conductance Gi and the time detection theshold TDT, in units of time. Roughly, Ci represents the doub- equal parts. Our results indicate that Ci timeâ€"growth le-layer capacity of the electrodeâ€"electrolyte inter- curves produce larger changes, detection times some- face Felice, Cady was one of the first to details. Gnan and Luedecke used 2. Other investigators Capacitance, Ci , and total conductance, G, were contributed to the subject using either the above- measured with a previously described laboratory mentioned instrument Suhren and Heeschen, ; custom-made equipment Felice et al. We did Neaves et al. The capacitance and medium conductance, while both impedance technique was also applied to monitoring types are measured separately in Ci and G, respec- total microbial load in meat Russell et al. A thermostatic bath, containing 32 culture cells, kept their temperature within Before each experiment, cells were washed and rinsed with distilled water and sterilized 20 min in autoclave at C ; thereafter, always under sterile conditions, they were filled with 4 ml of sterilized Fig. Electrical circuit equivalence between two electrodes. The equipment was connected to the electrodes, while another 4-ml aliquot was plate counted 72 h, at C. Milk samples were collected over 2 months from different dairy farms. We use the inverse to avoid distortion of the logarithmic initial phase in growth curves. To reduce noise or signal disturbances, air bubbles were removed and thermic transients were avoided. Besides, they were plotted in a These curves are examples of those obtained during the experi- ments, including curves of low and high slope. This relationship was used as calibration. In them, the TDT detection algorithm in- cluded in the equipment software filtered out artifacts 3. Results due to bubbles or lipid residues. The calibration regression line Fig. The linear regression of the data for Ci curves gave: The calculation contains points that growth curve with its conductive G and capacitive Ci parts are belong to raw milk assays of different dairy farms. The sample is raw milk in culture medium at C. The correlation coefficient was By and large, weakly instead, it was, charged substances are transformed into highly charged terminal products, for example, the break- IC 5 7. All these final 0. Moreover, with bacteria, the contribution to a ,0. Another advantage is a such as ethanol which tend to decrease the total slightly and statistically significant higher correlation conducting ionic content in the broth Ebina et al. In other words, according to the contains contributions due to the geometry rough- initial concentration given by SPC, we should have ness of the electrodes and also to the electrochemi- obtained a shorter detection time. When the anomal- cal characteristics of the interface Felice, As a rough approximation, and using data ob- 4. Discussion tained with similar material by NASA NASA KSC- , , we have estimated that Ci contains The method of using Ci to

quantify bacteria may contributions from the double-layer capacitance and, be useful in a dairy plant for the quality evaluation of in variable proportion, from the medium conduct- raw milk samples. Table 1 shows the advantages of ance. The latter component was included due to the using Ci instead of G curves to detect and quantify roughness of the electrodes Felice, The correlation coefficient When the microorganisms grow, they can modify the double- Cady, P. Progress in impedance measurements in micro- layer capacitance because bacterial metabolism in- biology. Thomas, Springfield, IL, pp. The same factors Colquhoun, K. Detection of affect also Gm Firstenberg-Eden and Eden, , Escherichia coli in potable water using direct impedance however, in our experiments, Ci appears to be more technology. Comparison of conductimetric and traditional plating techniques for detecting yeasts in fruit juices. The above analysis is just a guide to qualitatively J. Origin of changes in bipolar impedance components during bacterial pro- electrical impedance during the growth and fermentation pro- liferation. Theoretical studies should go deeper, cess of yeast in batch culture. Monitor digital de microorganismos: Sistema multicanal either resistive or reactive changes. Wiley, New York, pp. The impedancimetric method, using the interface Firstenberg-Eden, R. Electrochemical changes in media due to microbial growth. Methods 2, capacitance curves, is applicable for the detection â€" Principles of Applied Bio- tent. With it, we can obtain greater growth variations, medical Instrumentation, 3rd ed. Impedance measurements in raw milk as an alternative to the standart plate count. Food slightly but significantly better than those obtained Protect. Besides, we think the latter can be electrolyte impedance in the detection of bacterial growth. IEEE improved by modifying the incubation temperature. Eng 28 5 , â€" At Hz, medium conductance represents the Henschke, P. Detection of wine yeast by electronic methods. Electrochemical impedance spectros- complex mixture of medium conductance and copy of metal alloys. Briefs 17 1 , Separation of Neaves, P. A medium for the these two components requires more research. To Jorge Reinheimer for his advice and Susana Microbiol. Basan for her technical assistance. Supported by Pirovano, F. Im- pedimetric method for selective enumeration of specific yoghurt grants from CIUNT Consejo de Investigaciones de bacteria with milk-based culture media. Electronic measurement of bacterial growth. The effect of Valentinuzzi, M. Monitoring incubation temperature on recovery of mesophilic bacteria from of physiological events by impedance. Begell House, New Schmickler, W. New models for the York, pp. Rapid estimation 4 , â€" Impedance microbiologyâ€"a rapid measurements. The Malthus mi- Suhren, G. Impedance assays and the crobiological analyser as an aid in the detection of post- bacteriological testing of milk and milk products. Milchwis- pasteurization contamination of pasteurized milk. Netherlands senschaft 42 10 , â€" Impedance monitoring of bacterial activity.

Chapter 4 : Impedance microbiologyâ€"a rapid change for microbiologists | Stephen Forsythe - calendrierd

Impedance microbiology is the detection and quantification of bacterial growth by measuring the electrical impedance change during microbial metabolism which allows the identification of viable and nonviable cells.

Received Jun 8; Accepted Sep The use, distribution or reproduction in other forums is permitted, provided the original author s or licensor are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms. Abstract Impedance microbiology is a method that enables tracing microbial growth by measuring the change in the electrical conductivity. Potential acidifying performances of eighty strains belonging to Lactobacillus helveticus, Lactobacillus delbrueckii subsp. It is based on a principle that dates back to Stewart, but its application to food microbiology field is most recent and mainly associated to rapid detection of foodborne pathogenic bacteria Yang and Bashir, Impedance, applied to microbiology, can be defined as the resistance to flow of an alternating current that passes through a conducting microbial growth medium. During microbial growth, metabolic processes produce electrically measurable changes in the growth medium due to the metabolism of high-molecular weight nutrients into smaller charged ionic components that increase the electrical conductivity of the medium. Variation in electrical conductivity, monitored during time, is proportional to the change in the number of microorganisms and therefore the microbial growth can be measured Batrinou et al. Different systems, able to perform this measurement, are available. Common to all the systems is the measurement of an electronic signal that quantify the movement of ions between two electrodes conductance while, in some devices, the storage of charge at the electrodes medium interface capacitance is also measured Noble et al. Plotting of the continuous measurement of cumulative increase in conductance, or capacitance, graphically results in an impedance curve Rediers et al. Time to detection TTD for RABIT corresponds to the point where the cumulative change in conductivity from the baseline meets or exceeds a set value over a defined time interval Rediers et al. Detection Time DT for Malthus is obtained when a change in conductance over a threshold reference value set by the operator is observed Lanzanova et al. DT of Bactometer is the amount of time required to cause a series of significant deviations from baseline impedance values Noble et al. Recently, an intriguing unconventional approach to impedance microbiology was considered to detect bacteriophages responsible for cell lysis Mortari et al. The responses of microorganisms to specific environmental conditions, such as temperature, pH and aw, can be described by predictive microbiology, a sub-discipline of food microbiology dealing with the development of mathematical models Baranyi and Roberts, Several models have been developed to represent and predict microbial growth or inactivation in food and, nowadays, such models can be very useful in food technology and processing since they are applied to predict the outcome of fermentation processes under particular circumstances and to assess the effects of environmental conditions on microbial growth. Examples of primary models, widely applied to describe the growth of lactic acid bacteria, include sigmoidal equations, such as Logistic and Modified Gompertz models Chowdhury et al. This describes the changes of the microbial population density as a function of time using a limited number of kinetic parameters e. The Gompertz model provides a convenient mathematical tool that approximates the way in which microbiologists have traditionally estimated the graph of the growth kinetics Buchanan et al. Materials and methods Strains, media, and growth conditions Eighty strains representing four starter lactic acid bacteria species, Lactobacillus helveticus, Lactobacillus delbrueckii subsp. The strains, belonging to the collection of the Laboratory of Food Microbiology of the Department of Food Science of University of Parma, have been previously isolated from dairy matrixes and identified by16S rRNA sequencing. Table 1 Lactic acid bacteria strains used in this study.

Chapter 5 : Taking the impedance technique approach to real-time microbiology | Scientist Live

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Chapter 6 : Impedance microbiology - Wikipedia

IntroductionElectrical impedance, as a principle of transduction, has been applied in a wide variety of biomedical problems (Geddes and Baker,).One application lies in the field of microbiology, i.e., as a means to detect, quantify and even identify bacteria.