Compositions comprising a plurality of yeast cells, wherein said plurality of yeast cells have been cultured in the presence of an alternating electric field having a specific frequency and a specific field strength for a period of time sufficient to substantially increase the capability of said plurality of yeast cells to convert biologically available phosphorus in a culture medium into their own biomass. Also included are methods of making such compositions.
FIG. 1
YEAST COMPOSITIONS FOR CONVERTING BIO-AVAILABLE PHOSPHORUS IN A CULTURE MEDIUM TO INTRACELLULAR PHOSPHORUS

FIELD OF THE INVENTION

[0001] The invention relates to the use of yeast cells to incorporate biologically available phosphorus in a culture medium into their own biomass. These yeasts are useful in waste treatment, and can be obtained by growth in electromagnetic fields with specific frequencies and field strengths.

BACKGROUND OF THE INVENTION

[0002] Environmental pollution by urban sewage and industrial waste water has posed a serious health threat to living organisms in the world. Currently, the most common methods for large-scale waste treatment, such as water treatment, include the activated sludge technology and the biomembrane technology. These technologies rely on the innate abilities of myriad natural microorganisms, such as fungi, bacteria and protozoa, to degrade pollutants. However, the compositions of these natural microbial components are difficult to control, affecting the reproducibility and quality of water treatment. Moreover, pathogenic microbes existing in these activated sludge or biomembrane cannot be selectively inhibited, and such microbes usually enter the environment with the treated water, causing “secondary pollution.”

[0003] Further, most of the current technologies cannot degrade harmful chemicals such as pesticides, insecticides, and chemical fertilizers. These technologies also cannot alleviate eutrophication, another serious environmental problem around the world. Eutrophication is usually caused by sewage, industrial waste water, fertilizers and the like. It refers to waters (e.g., a lake or pond) rich in minerals and organic nutrients that promote a proliferation of plant life, especially algae, which reduces the dissolved oxygen content or otherwise deteriorates water quality. Eutrophication often results in the extinction of other organisms.

SUMMARY OF THE INVENTION

[0004] This invention is based on the discovery that certain yeast cells can be activated by electromagnetic fields of specific frequencies and field strengths to convert biologically available phosphorus, a major environmental pollutant, to intracellular phosphorus (i.e., incorporating biologically available phosphorus in their environs into their own biomass). Compositions comprising these activated yeast cells can therefore be used for waste treatment, for example, treatment of sewage, industrial waste water, surface water, drinking water, sediment, soil, garbage, and manure, to reduce the content of available phosphorus in the waste. Waste treatment methods using these compositions are more effective, efficient, and economical in preventing eutrophication than the conventional methods.

[0005] This invention embraces a composition comprising a plurality of yeast cells that have been cultured in an alternating electric field having a frequency in the range of about 80 MHz to 440 MHz (e.g., 86-120 or 410-430 MHz) and a field strength in the range of about 0.5 to 350 mV (e.g., 60-260 mV/cm). The yeast cells are cultured for a period of time sufficient to substantially increase the capability of said plurality of yeast cells to convert biologically available phosphorus in a culture medium into intracellular phosphorus. In one embodiment, the frequency and/or the field strength of the alternating electric field can be altered within the aforementioned ranges during said period of time. In other words, the yeast cells can be exposed to a series of electromagnetic fields. An exemplary period of time is about 12-400 hours, e.g., 228-368 hours.

[0006] Yeast cells that can be included in this composition are available from the China General Microbiological Culture Collection Center (“CGMCC”), a depository recognized under the Budapest Treaty (China Committee for Culture Collection of Microorganisms, Institute of Microbiology, Chinese Academy of Sciences, Haidian, P.O. Box 2714, Beijing, 100080, China). Useful yeast species include, but are not limited to, Saccharomyces cerevisiae and Saccharomyces carlsbergensis. For instance, the yeast cells can be of the strain Saccharomyces cerevisiae AS2.345, AS2.423, AS2.430, AS2.451, AS2.558, AS2.620, AS2.628, or IFU1203; or Saccharomyces carlsbergensis AS2.189.

[0007] This invention further embraces a composition comprising a plurality of yeast cells, wherein said plurality of yeast cells have been activated such that they have a substantially increased capability to convert biologically available phosphorus in a culture medium into intracellular phosphorus as compared to unactivated yeast cells. Included in this invention are also methods of making these compositions.

[0008] As used herein, “biologically available” or “assimilable” phosphorus refers to phosphorus that is readily available, useable, or assimilable by living organisms for survival and/or growth. Exemplary biologically available or assimilable phosphorus includes, but is not limited to, PO₄³⁻, H₂PO₄⁻, HPO₄²⁻, H₂PO₄⁻, other water-soluble inorganic phosphorus-containing compounds, and organic phosphorus-containing compounds.

[0009] A “substantial increase” means an increase of more than 10 (e.g., 10², 10³, 10⁴, 10⁵, or 10⁶) fold.

[0010] A “culture medium” refers to a medium used in a laboratory for selecting and growing a given yeast strain, or to liquid or solid waste in need of treatment.

[0011] Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Exemplary methods and materials are described below, although methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present invention. All publications and other references mentioned herein are incorporated by reference in their entirety. In case of conflict, the present specification, including definitions, will control. The materials, methods, and examples are illustrative only and not intended to be limiting.

[0012] Other features and advantages of the invention will be apparent from the following detailed description, and from the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. 1 is a schematic diagram showing an exemplary apparatus for activating yeast cells using electromagnetic fields. 1: yeast culture; 2: container; 3: power supply.
DETAILED DESCRIPTION OF THE INVENTION

[0014] This invention is based on the discovery that certain yeast strains can be activated by electromagnetic fields ("EMF") having specific frequencies and field strengths to become highly efficient in converting biologically available phosphorus to intracellular phosphorus. Yeast cells having this function are defined herein as belonging to the same "functional group." Compositions containing the activated yeast cells are useful in waste treatment.

[0015] Without being bound by any theory or mechanism, the inventor believes that EMFs activate or enhance the expression of a gene or a set of genes in yeast cells such that the yeast cells become active or more efficient in performing certain metabolic activities which lead to the desired phosphorus conversion result.

I. Yeast Strains Useful in the Invention

[0016] The types of yeasts useful in this invention include, but are not limited to, yeasts of the genera of Saccharomyces, Schizosaccharomyces, Sporobolomyces, Torulopsis, Trichosporon, Wickerhamia, Ashbya, Blastomyces, Candida, Citeromyces, Cryptococcus, Cryptosporidium, Debaromyces, Endomycopsis, Eremothecium, Geotrichum, Hansenula, Kluyvera, Lipomyces, Pichia, Rhodospirillum, and Rhodotorula.

[0017] Exemplary species within the above-listed genera include, but are not limited to, Saccharomyces cerevisiae, Saccharomyces bailii, Saccharomyces carlsbergensis, Saccharomyces chevalieri, Saccharomyces delbrueckii, Saccharomyces exigus, Saccharomyces fermentati, Saccharomyces lievus, Saccharomyces mohrii, Saccharomyces microellipsoides, Saccharomyces oviformis, Saccharomyces rouxii, Saccharomyces rouxii, Saccharomyces sake, Saccharomyces uvarum, Saccharomyces williamsii, Saccharomyces sp., Saccharomyces ludwigii, Saccharomyces sinensis, Saccharomyces bailii, Saccharomyces carlsbergensis, Schizosaccharomyces octosporus, Schizosaccharomyces pombe, Sporobolomyces roseus, Sporobolomyces salmonicolor, Torulopsis candida, Torulopsisfusamata, Torulopsis globosa, Torulopsis inconspicua, Trichosporon beihrendii, Trichosporon capitatum, Trichosporon cutaneum, Wickerhamiaglucoens, Ashbya gossypii, Blastomyces dermatisis, Candida albicans, Candida arborescens, Candida guilliermondii, Candida kruzei, Candida lamberca, Candida lipolytica, Candida parakrausei, Candida paraphilosis, Candida pseudotropicalis, Candida pulcherrima, Candida robusta, Candida rugosa, Candida tropicalis, Candida utilis, Citeromyces maitiensis, Cryptococcus ashbyii, Cryptococcus laurentii, Cryptococcus neoformans, Debaromyces hansenii, Debaromyces kloeckeri, Debaromyces sp., Endomyces fibuligera, Eremothecium ashbyii, Geotrichum candidum, Geotrichum ludwigi, Geonocardium robustum, Geotrichum suevebensis, Hansenula anomala, Hansenula arabitolgensis, Hansenula jadinii, Hansenula saturnus, Hansenula schneegii, Hansenula subpelliculosa, Kloeckera apiculata, Lipomyces starkeyi, Pichia farinosa, Pichia membranaefaciens, Rhodospiridium toruloides, Rhodotorula aurantiaca, Rhodotorula glutinis, Rhodotorula minuta, Rhodotorula rubra, and Rhodotorula sinesis.

[0018] Yeast strains useful for this invention can be obtained from laboratory cultures, or from publically accessible culture depositories, such as CGMCC and the American Type Culture Collection, 10801 University Boulevard, Manassas, Va. 20110-2209. Non-limiting examples of useful strains (with accession numbers of CGMCC) are: Saccharomyces cerevisiae Hansen AS2.346, AS2.423, AS2.430, AS2.451, AS2.558, AS2.620, AS2.628, and IFI1203; and Saccharomyces carlsbergensis AS2.189.

[0019] Although it is preferred, the preparation of the yeast compositions of this invention is not limited to starting with a pure strain of yeast. A yeast composition of the invention may be produced by culturing a mixture of yeast cells of different species or strains that have the same function, for example, converting biologically available phosphorus to intracellular phosphorus. The ability of any species or strain of yeast to perform this function can be readily tested by methods known in the art.

[0020] Certain yeast species that can be activated according to the present invention are known to be pathogenic to human and/or other living organisms. These yeast species include, for example, Ashbya gossypii, Blastomyces dermatisis, Candida albicans, Candida parakrausei, Candida tropicalis, Citeromyces maitiensis, Cryptococcus ashbyii, Cryptococcus laurentii, Cryptococcus neoformans, Debaromyces hansenii, Debaromyces kloeckeri, Debaromyces sp., and Endomyces fibuligera. Under certain circumstances, it may be less preferable to use such pathogenic yeasts in this invention. If use of these species is necessary, caution should be exercised to minimize the leak of the yeast cells into the final treatment product that enters the environment.

II. Application of Electromagnetic Fields

[0021] An electromagnetic field useful in this invention can be generated and applied by various means well known in the art. For instance, the EMF can be generated by applying an alternating electric field or an oscillating magnetic field.

[0022] Alternating electric fields can be applied to cell cultures through electrodes in direct contact with the culture medium, or through electromagnetic induction. See, e.g., FIG. 1. Relatively high electric fields in the medium can be generated using a method in which the electrodes are in contact with the medium. The method can be taken to prevent electrolysis at the electrodes from introducing undesired ions into the culture and to prevent contact resistance, bubbles, or other features of electrolysis from dropping the field level below that intended. Electrodes should be matched to their environment, for example, using Ag—AgCl electrodes in solutions rich in chloride ions, and run at as low a voltage as possible. For general review, see Goodman et al., Effects of EMF on Molecules and Cells, International Review of Cytology, A Survey of Cell Biology, Vol. 158, Academic Press, 1995.

[0023] The EMFs useful in this invention can also be generated by applying an oscillating magnetic field. An oscillating magnetic field can be generated by oscillating electric currents going through Helmholtz coils. Such a magnetic field in turn induces an electric field.

[0024] The frequencies of EMFs useful in this invention range from about 5 to 5000 MHz, e.g., from 80 to 440 MHz (e.g., 86-120 MHz or 410-430 MHz). Exemplary frequen-
cies are 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, and 430 MHz. The field strength of the electric field used in this invention ranges from about 0.5 to 350 mV/cm, e.g., from about 60 to 260 mV/cm. Exemplary field strengths are 68 and 240 mV/cm.

[0025] When a series of EMFs are applied to a yeast culture, the yeast culture can remain in the same container while the same set of EMF generator and emitters is used to change the frequency and/or field strength. The EMFs in the series can each have a different frequency or a different field strength; or a different frequency and a different field strength. Such frequencies and field strengths are preferably within the above-described ranges. In one embodiment, an EMF at the beginning of the series has a field strength identical to or lower than that of a subsequent EMF, such that the yeast cell culture is exposed to EMFs of progressively increasing field strength. Although any practical number of EMFs can be used in a series, it may be preferred that the yeast culture be exposed to a total of 2, 3, 4, 5, 6, 7, 8, 9 or 10 EMFs in a series.

[0026] By way of example, the yeast cells can be cultured in a first series of alternating electric fields each having a frequency in the range of 86 to 120 MHz and a field strength in the range of 60 to 260 mV/cm. The yeast cells are exposed to each EMF for about 24 hours. After culturing in the first series of EMFs, the resultant yeast cells are further incubated in a second series of alternating electric fields for a total of 24 to 132 hours. It may be preferred that the frequencies in the second series of alternating electric fields are identical to those of the first series in sequence and the field strengths in the second series are increased to a higher level within the range of 60 to 260 mV/cm.

[0027] Although the yeast cells can be activated after even a few hours of culturing in the presence of an EMF, it may be preferred that the activated yeast cells be allowed to multiply and grow in the presence of the EMF(s) for a total of 228-368 hours.

[0028] FIG. 1 illustrates an exemplary apparatus for generating alternating electric fields. An electric field of a desired frequency and intensity is generated by an AC source (3) capable of generating an alternating electric field, preferably in a sinusoidal wave form, in the frequency range of 5 to 5000 MHz. Signal generators capable of generating signals with a narrower frequency range can also be used. If desirable, a signal amplifier can be also be used to increase the output. The alternating electric field can be applied to the culture by a variety of means including placing the yeast culture in close proximity to the signal emitters. In one embodiment, the electric field is applied by electrodes submerged in the culture (1). In this embodiment, one of the electrodes can be a metal plate placed on the bottom of the container (2), and the other electrode can comprise a plurality of electrode wires evenly distributed in the culture (1) so as to achieve even distribution of the electric field energy. The number of electrode wires used depends on the volume of the culture as well as the diameter of the wires. In a preferred embodiment, for a culture having a volume up to 5000 ml, one electrode wire having a diameter of 0.1 to 1.2 mm can be used for each 100 ml of culture. For a culture having a volume greater than 1000 L, one electrode wire having a diameter of 3 to 30 mm can be used for each 1000 L of culture.

III. Culture Media

[0029] Culture media useful in this invention contain sources of nutrients assimilable by yeast cells. In this invention, a culture medium refers to a laboratory culture medium, or liquid or solid waste in need of treatment. Complex carbon-containing substances in a suitable form, such as carbohydrates (e.g., sucrose, glucose, fructose, dextrose, maltose, xylene, cellulose, starches, etc.) and coal, can be the carbon sources for yeast cells. The exact quantity of the carbon sources utilized in the medium can be adjusted in accordance with the other ingredients of the medium. In general, the amount of carbohydrates varies between about 0.1% and 5% by weight of the medium and preferably between about 0.1% and 2%, and most preferably about 1%. These carbon sources can be used individually or in combination. Among the inorganic salts which can be added to the culture medium are the customary salts capable of yielding sodium, potassium, calcium, phosphate, sulfate, carbonate, and like ions. Non-limiting examples of nutrient inorganic salts are (NH₄)₂HPO₄, KH₂PO₄, CaCO₃, MgSO₄, NaCl, KNO₃, and CaSO₄.

IV. Electromagnetic Activation of Yeast Cells

[0030] Yeasts of this invention convert biologically available or assimilable phosphorus in a culture medium, such as waste water, into their own biomass, i.e., intracellular phosphorus. Biologically available phosphorus convertible by these yeasts includes, but is not limited to, PO₄³⁻, H₂PO₄⁻, HPO₄²⁻, and H₂PO₄⁻, other water-soluble inorganic phosphorus-containing compounds, and organic phosphorus-containing compounds. Biologically available phosphorus in waste water causes undesired eutrophication of water bodies in the world.

[0031] To activate the innate ability of yeast cells to convert biologically available phosphorus into intracellular phosphorus, these cells can be cultured in an appropriate medium under sterile conditions at 25°C-30°C, e.g., 28°C, for a sufficient amount of time, e.g., 12-400 hours (for example, 228-368 hours) in an alternating electric field or a series of alternating electric fields as described above. An exemplary culture medium contains in per 1000 ml of sterile water: 10 g of sucrose, 3 g of (NH₄)₂HPO₄ (or other biologically available phosphorus), 1.2 g of NaCl, 0.2 g of MgSO₄·7H₂O, 3 g of CaCO₃·5H₂O, 0.3 g of CaSO₄·2H₂O, 0.3 g of KNO₃, and 0.5 g of yeast extract. The culturing process may preferably be conducted under conditions in which the concentration of dissolved oxygen is between 0.025 to 0.8 mol/m³, preferably 0.4 mol/m³. The oxygen level can be controlled by, for example, stirring and/or bubbling.

[0032] Subsequently, the yeast cells can be measured for their ability to convert biologically available phosphorus to intracellular phosphorus using standard methods, such as using ultraviolet spectrophotometry or the chemical oxygen demand ("COD") method. In an exemplary method, waste water from a phosphorus fertilizer manufacturer containing high levels of HPO₄²⁻, H₂PO₄⁻, and/or H₂PO₄⁻ is mixed with distilled water to achieve the following COD concentrations:
(1) 100–1,000 mg/L; (2) 1,000–5,000 mg/L; (3) 5,000–10,000 mg/L; and (4) 10,000–50,000 mg/L. The solutions are then inoculated with a dry yeast cell preparation at a concentration of 0.2–0.6 g/L, and cultured for 24–48 hours at 10–40°C. The COD levels of the solutions are then measured using standard techniques. The difference between the COD levels before and after 24–48 hours indicates the phosphorus-converting activity of the yeast cells. Another method for determining the phosphorus-converting abilities of the activated cells is described in the working example, infra.

[0033] Essentially the same protocol as described above can be used to grow activated yeast cells. To initiate the process, each 100 ml of culture medium is inoculated with yeast cells of the same functional group at a density of 10–10⁷ cells/ml, preferably 3×10⁶–10⁷ cells/ml. The culturing process is carried out at about 20–40°C, preferably at about 25–28°C, for 48–96 hours. The process can be scaled up or down according to needs. For an industrial scale of production, seventy-five liters of a sterile culture medium are inoculated with the yeast cells. This culture medium consists of 10 L of the culture medium described above for this particular yeast functional group, 30 kg of starch, and 65 L of distilled water. At the end of the culturing process, the yeast cells may preferably reach a concentration of 2×10¹⁰ cells/ml. The cells are recovered from the culture by various methods known in the art, and stored at about 15–20°C. The yeast should be dried within 24 hours and stored in powder form.

V. Acclimatization of Yeast Cells To Waste Environment

[0034] In yet another embodiment of the invention, the yeast cells may also be cultured under certain conditions so as to acclimatize the cells to a particular type of waste. This acclimatization process results in better growth and survival of the yeasts in a particular waste environment.

[0035] To achieve this, the yeast cells of a given functional group can be mixed with waste material from a particular source at 10⁶ to 10⁷ cells (e.g., 10⁶ cells) per 1000 ml. The yeast cells are then exposed to an alternating electric field as described above. The strength of the electric field can be about 100 to 400 mV/cm (e.g., 120–250 mV/cm). The culture is incubated at temperatures that cycle between about 5°C to about 45°C at a 5°C increment. For example, in a typical cycle, the temperature of the culture may start at 5°C and be kept at this temperature for about 1–2 hours, then adjusted up to 10°C and kept at this temperature for 1–2 hours, then adjusted to 15°C and kept at this temperature for about 1–2 hours, and so on and so forth, until the temperature reaches 45°C. Then the temperature is brought down to 40°C and kept at this temperature for about 1–2 hours, and then to 35°C and kept at this temperature for about 1–2 hours, and so on and so forth, until the temperature returns to 5°C. The cycles are repeated for about 48–96 hours. The resultant yeast cells are then dried and stored at 0–4°C.

VI. Manufacture of the Waste Treatment Compositions

[0036] The yeast cells of this invention can be mixed with an appropriate filler, such as rock powder and coal ash at the following ratio: 600 L of yeast cell culture at 2×10¹⁰ cells/ml and 760 kg of filler materials. The mixture is quickly dried at a temperature below 65°C for 10 minutes in a dryer, and then further dried at a temperature below 70°C for no more than 30 minutes so that the water content is less than 7%. The dried composition is then cooled to room temperature for packaging.

[0037] These dried yeast compositions may be used to treat polluted surface water, sewage, or any other type of waste water. To treat polluted surface water, a yeast solution may be prepared by adding 1 kg of the dried yeast composition to 30 L of clean water. The yeast solution is then sprayed onto the polluted surface water at about 1–3 L of the solution per square meter of the polluted surface water. To treat sewage or any other type of waste water, a yeast solution may be prepared by adding about 1 kg of the dried yeast composition to 10–30 L of clean water. The yeast solution is incubated at 10–35°C for 24–48 hours. The resultant yeast solution is then added to the waste water at about 3–20 L of the solution per liter of waste water.

[0038] In order that this invention be more fully understood, the following example is set forth. This example is for the purpose of illustration only and is not to be construed as limiting the scope of the invention in any way.

VII. Example: Conversion of PO₄³⁻, H₃PO₄⁻, and/or H₂PO₄⁻ in a Culture Medium Into Intracellular Phosphorus

[0039] Saccharomyces cerevisiae Hansen AS2.620 cells were cultured in the presence of a series of alternating electric fields in the following sequence: the yeast cells were exposed to (1) an alternating electric field having a frequency of 98 MHz and a field strength of 68 mV/cm for 24 hours; (2) then to an alternating electric field having a frequency of 112 MHz and a field strength of 68 mV/cm for 24 hours; (3) then to an alternating electric field having a frequency of 108 MHz and a field strength of 68 mV/cm for 24 hours; (4) then to an alternating electric field having a frequency of 118 MHz and a field strength of 68 mV/cm for 24 hours; (5) then to an alternating electric field having a frequency of 98 MHz and a field strength of 240 mV/cm for 24 hours; (6) then to an alternating electric field having a frequency of 112 MHz and a field strength of 240 mV/cm for 24 hours; (7) then to an alternating electric field having a frequency of 108 MHz and a field strength of 240 mV/cm for 42 hours; and (8) finally to an alternating electric field having a frequency of 118 MHz and a field strength of 240 mV/cm for 42 hours.

[0040] To test the ability of the EMF-treated AS2.620 cells to convert biologically available phosphorus to intracellular phosphorus, waste water or filtrate from animal manure or garbage was supplemented with Na₃PO₄ to reconstitute a solution containing Na₃PO₄ at 200 mg/L. 0.1 ml of the EMF-treated AS2.620 cells at a concentration higher than 10 cells/ml was added to 100 ml of the Na₃PO₄ solution and cultured at 28°C for 48 hours (solution A). One hundred units of the Na₃PO₄ solution containing the same number of non-treated yeast cells (solution B) or containing no yeast cells (solution C) were used as controls. After 48 hours of incubation, the solutions were examined using ultraviolet spectrophotometry. The results showed that after 48 hours of incubation, the Na₃PO₄ concentration in solution A
decreased more than 23% relative to solution C. In contrast, the \( Na_3PO_4 \) concentration in solution B had no significant change relative to solution C.

[0041] While a number of embodiments of this invention have been set forth, it is apparent that the basic constructions may be altered to provide other embodiments which utilize the compositions and methods of this invention.

What is claimed is:

1. A composition comprising a plurality of yeast cells, wherein said plurality of yeast cells have been cultured in the presence of an alternating electric field having a frequency in the range of 80 to 440 MHz and a field strength in the range of 0.5 to 350 mV/cm for a period of time sufficient to substantially increase the capability of said plurality of yeast cells to convert biologically available phosphorus in a culture medium into intracellular phosphorus.

2. The composition of claim 1, wherein said frequency is in the range of 86 to 120 MHz or 410 to 430 MHz.

3. The composition of claim 1, wherein said yeast cells are cells of the species \textit{Saccharomyces cerevisiae} or \textit{Saccharomyces carlsbergensis}.

4. The composition of claim 1, wherein said yeast cells are cells of the strain deposited at The China General Microbiological Culture Collection Center with an accession number selected from the group consisting of AS2.346, AS2.423, AS2.430, AS2.451, AS2.558, AS2.620, AS2.628, IFFI 1203, and AS2.189.

5. The composition of claim 1, wherein said biologically available phosphorus is \( PO_4^{3-} \), \( HPO_4^{2-} \), \( H_2PO_4^- \), or \( H_3PO_4 \).

6. The composition of claim 5, wherein said frequency is in the range of 86 to 120 MHz and said field strength is in the range of 60 to 260 mV/cm.

7. A composition comprising a plurality of yeast cells, wherein said plurality of yeast cells have been activated such that they have a substantially increased capability to convert biologically available phosphorus in a culture medium into intracellular phosphorus as compared to unactivated yeast cells.

8. A method of preparing a yeast composition, comprising culturing a plurality of yeast cells in the presence of an alternating electric field having a frequency in the range of 80 to 440 MHz and a field strength in the range of 0.5 to 350 mV/cm for a period of time sufficient to substantially increase the capability of said plurality of yeast cells to convert biologically available phosphorus in a culture medium into intracellular phosphorus.

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