Preparation and diabetic use of gibberellins.

Application of compounds of formula (1) (Gibberellins) and their derivatives for the preparation of a pharmaceutical composition or medicaments for the treatment of diabetes, its complications and associated conditions, including obesity, micro and macro vascular diseases, nephropathy, neuropathy, eye diseases, diabetic ulcerations and the like. The method results the normalization of serum glucose level and other physiological conditions.

Field of the invention:

The present invention relates to the application of a group of compounds known as Gibberellins and their derivatives for the preparation of a pharmaceutical composition for the treatment of diabetes and related conditions, as well as a method for treating these and other conditions by administering Gibberellins and/or their pharmaceutically acceptable salts or esters including glycoside esters, active esters or lactones. Moreover, this invention relates to the manufacture and the use of a medicament for treating diabetes and related conditions thereof. Furthermore, the application of Gibberellins and their derivatives especially when administered orally, by injection, by transdermal patches, or by inhalation, can be used as a substitute for insulin and/or its fragment derivatives and/or IGFs (Insulin-like Growth Factors) treatment or as a choice of combination therapy with insulin, its fragment derivatives, IGF, growth factors or other pharmaceutically compatible anti-diabetic agents for the treatment of diabetes and related conditions.

Background of the invention:

This invention relates to a novel application of Gibberellins in veterinary and human medicines. In particular the invention concerns pharmaceutical formulations containing Gibberellins and their use for the treatment of diabetes including type 1 and type 2 diabetes and their complications and associated conditions including obesity, micro and macro vascular diseases, nephropathy, neuropathy, eye diseases, diabetic ulcerations and the like.

Gibberellins are a series of naturally occurring compounds, which are known as plant growth regulators with wide application in the plant kingdom [1]. They have also been isolated from metabolites of some microorganisms, such as Gibberella fujikuroi [2]. Gibberellins, especially Gibberellic Acid (Gibberellin A_3), and its mixture with Gibberellin A_4 and/or Gibberellin A_7 which are commercially available, have been extensively applied in agriculture to increase the growth of some fruits (strawberries and grapes) and vegetables (tomatoes, cabbages and cauliflowers), also as food additive in the malting of barley [3].

[1]. J. MacMillian, et al. "Isolation and Structure of Gibberellin From Higher Plants". Adv. Chem. Ser 28, 18~24, (1961).

[2].

(a) P.J. Curtis et al. Chem. & Ind. (London) 1066, (1954).

(b) B.E. Cross, J. Chem. Soc. 4670, (1954).

(c) P.W. Brian et al, U.S. 2,842,051.

(d) C.T. Calam et al, U.S. 2,950,288.

(e) A.J. Birch et al, U.S. 2,977,285.

[3].

(a) M. Devlin, Plant Physiology, New York, Reinhold, (1966).

(b) P.W. Brian et al, Plant Physiol, 5,669 (1955).

(c) A.K Mehta et al, J. Hostic Sci 4, 167 (1975).

(d) R.J. Weavor, Adv. Chem. Ser 28, 89 (1961).

(e) F.G. Gustafson, Plant Physical 35, 521 (1960).

(f) Fed. Reg. 25, 2162 (1960).

Gibberellin A_3 and its mixture of Gibberellin A_4 and/or A_7 can be obtained by fermentation of microorganisms such as Gibberella fujikuroi. The crude compounds can be isolated and purified to afford a high purity crystalline product. The other derivatives of Gibberellin can be obtained by either semi-synthetic route from Gibberellin A_3 or total synthesis which have been well-documented [4].

[4] .

(a) The Merck Index, 12, 4426, literatures cited herein.

(b) Furber M., et al., "New Synthesis Pathways From Gibberellins to Autheridiogens Isolated From the Fern Genus Anemia", J. of Org. Chem. vol 55, No. 15, 4860~4870 (1990).

(c) Mander L. N., et al., "C-18 hydroxylation of Gibberellins", J. C. S., Perkin Trans. 1 (17), 2893~2894 (2000).

(d) Pour M. et al., "Synthesis of 3,12-Dihydroxy-9,15-Cyclo Gibberellins", Tetrahedron 54(45), 13833~13850 (1998).

(e) Liu J. P. et al., "A General Protocol For the Hydroxylation of C-14 in Gibberellins Synthesis of 14-Beta-hydroxy-Gibberellin A_1 Methyl Ester", Tetrahedron 54(38), 11637~11650 (1998).

(f) Pour M, et al., "Synthetic and Structural Studies on Novel Gibberellins", Pure and Applied Chemistry 70(2), 351~354 (1998); "Synthesis of 12-Hydroxy-9,15-Cyclo-Gibberellins", Tetrahedron Letters, 39(14), 1991~1994 (1998); Australian J. of Chemistry 50(4), 289~299 (1997).

(g) King G. R. et al., "A New and Efficient Strategy for the Total Synthesis of Polycyclic Diterpenoids – The Preparation of Gibberellins (+/-)-GA_{103} and (+/-)-GA_{73}", J. Am. Chem. Soc. 119(16), 3828~3829 (1997).

(h) Mander L. N., "Synthesis of 12-Hydroxy-C-20-Giebberellin from Gibberellin A_3", Tetrahedron 53(6), 2137~2162 (1997) and literatures cited herein.

Furthermore, the extraction and isolation of different Gibberellins from different plants, shoots, fruits and seeds have also been widely published [5].

[5].

(a) Pearce D.W., et al., Phytochemistry, 59(6), 679~687 (2002).

(b) Chang S. T., et al., Physiologia Plantarum, 112(3), 429~432 (2001).

(c) Nakayama M. et al., Phytochemistry, 57(5), 749~758 (2001); 48(4), 587~593 (1998).

(d) Blake P. S., et al., Phytochemistry, 55(8), 887~890 (2000); 53(4), 519~528 (2000).

(e) Koshioka M., et al., J. of the Japanese Society for Horticultural Science, 68(6), 1158~1160 (1999); 67(6), 866~871 (1998).

(f) Mander L. N. et al., Phytochemistry, 49(8), 2195~2206 (1998); 49(6), 1509~1515 (1998).

(g) Wynne G. et al., Phytochemistry, 49(7), 1837~1840 (1998).

Gibberellins have previously been used for anti-inflammation, treatment of prostatitis and psoriasis, treatment of tumor, and for ulcer and wound healing [6].

[6].

(a) U.S. 4424232 1/1984 Parkinson

(b) French 2597339 10/1987

(c) U.S. 5487899 1/1996 Davis

(d) U.S. 5580857 12/1996 Oden

(e) AUS. 695054 11/1998 Wu

(f) U.S. 6121317 9/2000 Wu

We have now found application of Gibberellin or its derivatives for the treatment of diabetes including type 1 and type 2 diabetes and their related conditions.

Disclosure of the invention:

It has now been found that Gibberellins possess mammalian growth factor (such as IGF, EGF) like properties in our laboratory.

The experimental results (examples 3 and 4) suggested that Gibberellins, which are generated by plants and microbes, act as broad-spectrum binders binding to a range of growth factor receptors. They differ from the growth factors found in animals, each of which has a high affinity for a specific receptor. This is the result of evolution. The biological systems of plants and microbes produce biological substances acting on a broader (less specific) base than that of the more complex life forms such as animals.

Since Gibberellins are smaller molecules than growth factors, the binding of Gibberellins on the growth factor receptors is probably weaker. In the presence of low level of growth factors, Gibberellins bind to vacant growth factor receptors to stimulate cell growth and other functions. Under this condition, Gibberellins perform the functions of the growth factors. In the presence of normal level of growth factors, the growth factors bind to their receptors more

readily due to their higher affinity for those receptor sites. The physical bulkiness of these growth factors leaves no room or very little room at the receptor sites for which Gibberellins can bind. This results in Gibberellins being ineffective when growth factors with sufficient binding affinity are present in sufficient quantities. This mechanism provides a very good profile for Gibberellins acting as a substitute or sensitizer for growth factors including IGF since the presence of excess Gibberellins will not interfere with the normal functions of these growth factors.

Diabetes mellitus is a chronic disorder manifested by hyperglycemia and altered lipid and protein metabolism. According to the American Diabetes Association, more than 13 million people in the U.S. suffer from diabetes, and each year some 650,000 new cases are identified. The introduction of insulin and of sulfonyl ureas represented important landmarks in the treatment of diabetes mellitus. Insulin like growth factor – 1 (IGF-1), a molecule with structure homology to insulin, has its own specific receptor, the type-1 IGF receptor, through which it elicits a variety of metabolic effects that are similar to insulin. The discovery of the active region of human growth factor responsible for the insulin like actions of the molecule has led to the development of new anti-diabetic peptide agents. In addition, growth factors are polypeptides that regulate the replication, differentiation and metabolic homeostasis cells. They increase the growth and/or survival of neurons. In pre-clinical testing for the treatment of various neurological disorders including diabetic neuropathies, IGF-2 increased the rate of nerve regeneration. Furthermore, elevated intracellular concentrations of c-AMP potentiate glucose-dependent insulin secretion from pancreatic β-cells. Gibberellins have been found to increase the activity of adenylate and gryanylate cyclase, so that the intracellular concentrations of c-AMP and c-GMP may be increased by the administration of Gibberellins to potentiate in turn glucose-dependent insulin secretions from pancreatic β-cells. Gibberellins may thus be seen to have application in the treatment of diabetes.

The animal experiment results (examples 5 & 6) showed diabetic rats treated with 5mg/kg of Gibberellin A_3 or a mixture of A_3 and A_4 or A_7 returned

their serum glucose level to the normal, as well as their body weights. It indicated that Gibberellins may be effective in the treatment of diabetes.

The toxicity to mammals of Gibberellin A_3 is extremely low. The acute oral LD_{50} for rats and mice is reported to be 6.3g/kg [7a] and >15g/kg [7b] respectively. In 90-day feeding trials, the no effect level for rats and dogs was >1g/kg/day [7b]. It is non-irritating to skin and eyes [7b]. No indication has been found of carcinogenicity [7c]. Classifications: WHO Toxicity Class Table 5 (least hazardous class product, unlikely to present acute hazard in normal use); EPA Toxcity class III (second least hazardous classification).

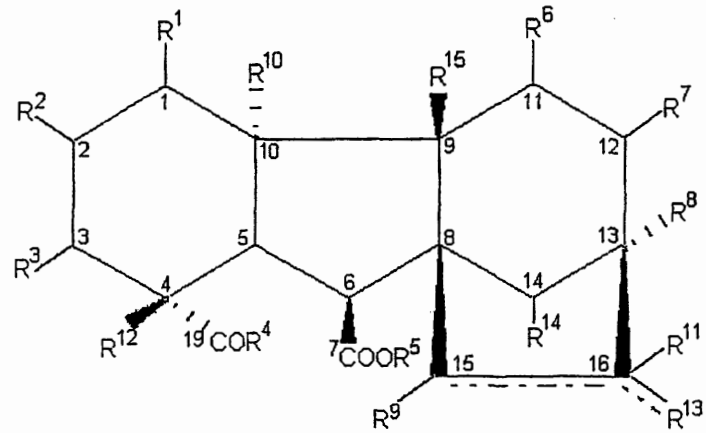
[7].

(a) NTP Chemical Repository, http://ntpserver.niehs.nih.gov/htdocs/CHEM_H&S/NTP_CHEM7/Radian77-06-5.html

(b) The Agrochemicals Handbook, Royal Society of Chemistry, August 1991.

(c) Gold L. S., Slone T. H., Ames B. N. (2001), Pesticide Residues in Food and Cancer Risk: A Critical Analysis, Publications from the Carcinogenic Potency Project, in Handbook of Pesticide Toxicity, Second Edition, (R. Krieger, ed.), Academic Press.

Thus one aspect of this invention relates to use of compounds of Formula (1) (Gibberellins) or their derivatives for the treatment of diabetes and its complications and associated conditions including obesity, micro- and macro-vascular diseases, nephropathy, neuropathy, eye diseases, diabetic ulcerations and the like. In another aspect of the invention, there is provided a pharmaceutical formulation for the treatment of diabetes and related conditions including obesity, micro- and macro-vascular diseases, nephropathy, neuropathy, eye diseases, diabetic ulcerations and the like, said pharmaceutical formulation including Gibberellins, and/or their pharmaceutically acceptable salts or esters.



Gibberellins have the following formula:

Formula (1)

wherein

R^1 is H or a group –O-R^{20}, where R^{20} is H, a glycosylic ether group (glycoside ether), $C_{1\sim6}$ alkyl group, or R^1 together with R^2 or R^{10} forms a bond (C_1– C_2 or C_1-C_{10} double bond, respectively);

R^2 is H or a group –O-R^{21}, where R^{21} is H, a glycosylic ether group (glycoside ether), or together with R^4 forms a bond (lactone) or R^2 together with R^1 or R^3 forms a bond (C_1-C_2 or C_2-C_3 double bond, respectively);

R^3 is H, =O, or –O-R^{22}, where R^{22} is H or a glycosylic ether group (glycoside ether), or R^3 together with R^2 forms a bond (C_2-C_3 double bond);

R^4 is OH, or –OR^{23}, where R^{23} is unsubstituted or substituted $C_{1\sim20}$ alkyl, allyl, aryl, arylalkyl, amidine, -$NR^{24}R^{25}$ or an unsaturated or saturated ring containing one or more hetero-atoms selected from the group consisting of nitrogen, oxygen and sulfur; R^{24} and R^{25} may or may not be the same, are hydrogen, or $C_{1\sim20}$ alkyl, allyl, aryl, arylalkyl or an unsaturated or saturated ring containing one or more hetero-atoms selected from the group consisting of nitrogen, oxygen and sulphur; or R^4 together with R^{21} or R^{28} forms a bond (lactone);

R^5 is H or a glycosylic ester (glycoside ester) group, or unsubstituted or substituted (e.g. halogenated) $C_{1\sim20}$ alkyl esters, allyl esters, aryl esters, arylalkyl esters, active esters (such as phenacyl ester, pivaloyl ester);

R^6 is H or OH or together with R^7 forms a bond (C_{11}-C_{12} double bond);

R^7 is H, =O, or $-OR^{26}$, where R^{26} is H or a glycosylic ether group (glycoside ether) or R^7 together with R^6 forms a bond (C_{11}-C_{12} double bond);

R^8 is H, hydroxyl, mercaptan, or halogen (e.g. F, Cl), amino, azido, $NR^{24}R^{25}$, unsubstituted or substituted (e.g. halogenated) $C_{1\sim20}$ alkyl, allyl, aryl, or arylalkyl, or $-OR^{27}$, where R^{27} is a glycosylic ether group (glycoside ether);

R^9 is H or OH, or together with R^{15} forms a bond (C_9-C_{15} bond);

R^{10} is H, CH_3, CHO, COOH, or a glycosylic ester (glycoside ester) of said COOH, CH_2O-R^{28} or $-OR^{28}$, where R^{28} is H or together with R^4 forms a bond (lactone) or R^{10} together with R^1 forms a bond (C_1-C_{10} double bond);

R^{11} is H, or OH or is absent;

R^{12} is CH_3, CH_2OH, COOH or a glycosylic ester (glycoside ester) of said COOH;

R^{13} is methylene, or a divalent hetero-atom, or NR^{29}, where R^{29} is NHR^{30} or OR^{30} where R^{30} is H, or $C_{1\sim20}$ alkyl, aryl, alkylaryl; and a double bond is present between C_{16} and R^{13} when R^{11} is absent; or R^{13} is H, OH, CH_3 CHO, CH_2X, where X is halogen (e.g. F, Cl); $CHNR^{29}$ where R^{29} is NHR^{30} or OR^{30} where R^{30} is H, or $C_{1\sim20}$ alkyl, aryl, alkylaryl when R^{11} is H or OH; with the proviso that where R^{11} is OH, R^{13} is not OH

R^{14} is H or OH;

R^{15} is H, or together with R^9 forms a bond (C_9-C_{15} bond);

Pharmaceutically acceptable derivatives, including lactones, esters and salts of compounds of Formula (1), include alkali metal salts (e.g. Na^+, K^+), alkaline

earth metal salts (e.g. Ca^{2+}, Mg^{2+}), metal salts (e.g. Zn^{2+}, Al^{3+}), and salts of ammonium, organic bases (such as lidocaine, or $NR^{16}R^{17}R^{18}R^{19}$ where R^{16}, R^{17}, R^{18}, R^{19}, which may be the same or not the same, are hydrogen, C_{1-20} alkyl, alkanol, aryl) thereof.

The dotted line together with the solid line indicate that a double bond may be situated between two of the three carbon atoms connected by the dotted and solid lines; with the proviso that a double bond is not present if R^{11} is an OH group.

Since Formula (1) complies with normal valence rules, this leads to the further provisos as follows:
R^1 and R^2 cannot form a bond if R^{10} and R^1 and/or R^2 and R^3 form a bond; R^{10} and R^1 cannot form a bond if R^{10} and R^{23} form a bond; R^2 and R^1 or R^2 and R^3 cannot form a bond if R^4 and R^{21} form a bond.

In the case of Gibberellin A_3, R^1 together with R^2 forms a bond (C_1-C_2 double bond); R^3 is β-OH, R^4 together with R^{28} forms a bond (lactone); R^5, R^6, R^7, and R^9 are hydrogen, R^8 is OH, R^{11} is absent; R^{12} is methyl; R^{13} is methylene, a double bond is present between C_{16} and R^{13}; R^{14} and R^{15} are hydrogen.

The most readily available Gibberellins are Gibberellin A_3 and its mixture with Gibberellin A_4 and/or Gibberellin A_7 from the fermentation of Gibberella fujikuroi. Although the methods of isolation and purification of Gibberellins including solvent extraction, and chromatography have been published as mentioned in the background of the invention, a simple and efficient process for isolation and purification is still needed. In this invention a practical process for the large scale production of Gibberellin A_3 is provided, comprising the steps of incubating a Gibberellin-producing strain of microorganism in a fermentation broth until the concentration of Gibberellins reaches about 3000µg/ml broth, followed by:

(a) adjusting the pH of the fermentation broth to pH 6.5 to 7.0 and filtering to obtain a filter cake of microorganism mycelium, and a filtrate;

(b) washing the filter cake with water and combining the washing with the filtrate to form an aqueous solution;

(c) concentrating the aqueous solution;

(d) mixing the aqueous solution with an organic solvent at a temperature of 5 to 10°C and adjusting the pH of the mixture to less than 2.0;

(e) allowing the mixture to separate into an aqueous phase and a first organic phase and removing the first organic phase;

(f) re-extracting the aqueous phase from step (f) with organic solvent to obtain a second organic phase;

(g) combining the first and second organic phases and concentrating to form a concentrated organic solution;

(h) heating the concentrated organic solution at 60-70°C for 3 to 4 hours with stirring, until the precipitation of solid matter ceases;

(i) cooling the concentrated organic solution to room temperature and filtering to obtain a precipitate;

(j) washing the precipitate in cold organic solvent and drying to obtain an off-white solid containing about 80% Gibberellin A_3, about 4% Gibberellin A_4 and about 4% Gibberellin A_7.

Optionally, the invention further comprises the steps of:

(k) dissolving the off-white solid in a mixture of 32.6% methanol, 2.2% water and 65.2% acetone to obtain a Gibberellin solution;

(l) diluting the Gibberellin solution with a 10:1 mixture of organic solvent and water;

(m) filtering the diluted Gibberellin solution and concentrating the filtrate by vacuum evaporation;

(n) heating the concentrate to a temperature of 60 to 80°C for 2 to 3 hours with stirring , cooling to room temperature and filtering to obtain a solid crystalline precipitate;

washing the precipitate with cold ethyl acetate and drying to obtain Gibberellin crystals at >95% purity.

Furthermore, processes for the preparation of Gibberellin salts and esters are disclosed. In particular, the invention includes a process for obtaining the sodium salt of Gibberellin, comprising the steps of:

(a) dissolving Gibberellin A_3 in methanol;

(b) adding the Gibberellin solution to an equimolar aqueous solution of $NaHCO_3$;

(c) evaporating the mixed solutions to dryness to obtain a solid residue;

(d) dissolving the residue in water and freeze drying to obtain Gibberellin A_3 sodium salt.

The invention further includes a process for obtaining the zinc salt of Gibberellin, comprising the further steps of dissolving Gibberellin A_3 sodium salt in water, passing the solution through a column loaded with a zinc ion-exchange resin, washing the column with water, collecting and combining the effluent and washings and removing the water to obtain Gibberellin A_3 zinc salt.

The invention further includes a process for obtaining the ethyl ester of Gibberellin, comprising the steps of:

(a) dissolving Gibberellin A_3 in a 50:1 ratio mixture of acetone to water;

(b) mixing the Gibberellin A_3 solution with equimolar amounts of triethylamine and ethyl chloroformate, and a one tenth molar amount of N-methyl morpholine, and stirring at -15°C for 20 minutes;

(c) diluting the resultant mixture with anhydrous ethanol and stirring at room temperature;

(d) evaporating the diluted mixture to dryness and partitioning the residue between ethyl acetate and water in a 6:1 ratio;

(e) separating the ethyl acetate layer, washing with 2% HCl, followed by water, followed by 5% $NaHCO_3$, followed by water, and evaporating under reduced pressure to dryness to give Gibberellin A_3 ethyl ester.

References hereinafter to the compounds of formula (1) include the compounds of formula (1) and their pharmaceutically acceptable derivatives including salts, esters and lactones thereof.

Pharmaceutically acceptable compositions of the compounds of formula (1) may also be formed by combining them with one or more other active ingredients, for example insulin, insulin-like polypeptides, insulin fragment derivatives, IGFs, IGF fragments, growth factors, or other pharmaceutically compatible anti-diabetic agents for the treatment of diabetes and related conditions.

The compounds of formula (1) possess activity as insulin and insulin like agonists and/or sensitizers for the treatment of diabetes, its complications and associated conditions including obesity, micro and macro vascular diseases, nephropathy, neuropathy, eye diseases, diabetic ulcerations and the like. There is thus provided in a further aspect of the invention, the compounds of formula (1) for use as an active therapeutic agent in the treatment of diabetes and related conditions.

In a further aspect of the invention there is provided a method of manufacturing a pharmaceutical composition, comprising combining a compound of formula (1) and/or its derivatives with a pharmaceutically acceptable carrier.

In a further aspect of the invention, there is provided a method for the treatment of diabetes and related conditions in animals including humans comprising administering an effective amount of the compounds of formula (1).

There is also provided in a further aspect of the invention, the use of the compounds of formula (1) for the manufacture of a pharmaceutical composition for the treatment of diabetes and related conditions.

The amount of the compounds of formula (1) required for use in the treatment of diabetes and related conditions will vary with the rate of administration, the nature of the condition being treated and the age and condition of the animal including human patients and will ultimately be at the discretion of the attendant veterinarian or medical doctor.

In general a suitable dose will be in the range of from about 0.1µg to 100mg/kg of body weight per day, preferably in the range of 50µg to 20mg/kg/day.

Treatment is preferably commenced after or at the time diabetes occurs and continues when it is needed. It is also possible to use the compounds of formula (1) as a prevention treatment.

Suitable treatment is given 1~4 times daily, and continued when it is needed. Alternatively, in the case of using a time release formulation, the treatment may be given once every 2 days to 1 week.

The desired dose may be presented in a single dose or as divided doses administered at appropriate intervals, for example as two, three, four or more sub-doses per day.

The compounds of formula (1) are conveniently administered in unit dosage form for example containing 0.1 to 500mg of active ingredient per unit dosage form. While it is possible that, for use in therapy, the compounds of formula (1) will be administered as the raw chemical, it is preferable to present the active ingredient as a pharmaceutical formulation.

The invention thus further provides a pharmaceutical formulation including the compounds of formula (1) or a pharmaceutically acceptable derivative thereof together with one or more pharmaceutically acceptable carriers therefor and, optionally, other therapeutic and/or prophylactic ingredients. The carrier(s) must be 'acceptable' in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof.

Pharmaceutical formulations include those suitable for oral, rectal, nasal, topical (including buccal and sub-lingual), vaginal or parenteral (including intramuscular, intradermal, sub-cutaneous and intravenous) administration or in a form suitable for administration to the gastrointestinal tract, or in a form suitable for administration to the respiratory tract (including the nasal passages)

for example by inhalation or insufflation or for intradermal or sub-cutaneous implantation or for transdermal patch. The formulations may, where appropriate, be conveniently presented in discrete dosage units and may be prepared by any of the methods known in the art of pharmacy. All methods include the step of bringing into association the active compound with liquid carriers or finely divided solid carriers or both and then, if necessary, shaping the product into the desired formulation.

Pharmaceutical formulations suitable for oral administration may be presented as discrete units such as capsules, cachets or tablets each containing a predetermined amount of the active ingredient; as a powder or granules; as a solution, a suspension or as an emulsion. The active ingredient may also be presented as a bolus, electuary or paste. Tablets and capsules for oral administration may contain conventional excipients such as binding agents, fillers, lubricants, disintegrants, or wetting agents. The tablets may be coated according to methods well known in the art. Oral liquid preparations may be in the form of, for example, aqueous or oily suspensions, solutions, emulsions, syrups or elixirs, or may be presented as a dry product for constitution with water or other suitable vehicle before use. Such liquid preparations may contain conventional additives such as suspending agents, emulsifying agents, non-aqueous vehicles (which may include edible oils), or preservatives.

The compounds of formula (1) may also be formulated for parenteral administration (e.g. by injection, for example bolus injection or continuous infusion) and may be presented in unit dose form in ampoules, pre-filled syringes, small volume infusion or in multi-dose containers with an added preservative. The compositions may take such forms as suspensions, solutions, or emulsions in oily or aqueous vehicles, and may contain formulation agents such as suspending, stabilizing and/or dispersing agents. Alternatively, the active ingredient may be in powder form, obtained by aseptic isolation of sterile solid or by lyophilisation from solution, for constitution with a suitable vehicle, e.g. sterile, pyrogen-free water, before use.

For topical administration to the epidermis the compounds of formula (1) may be formulated as ointments, creams or lotions, or as a transdermal patch. Ointments and creams may, for example, be formulated with an aqueous or oily base with the addition of suitable thickening and/or gelling agents. Lotions may be formulated with an aqueous or oily base and will in general also contain one or more emulsifying agents, stabilizing agents, dispersing agents, suspending agents, thickening, or colouring agents.

For topical administration in the mouth, the compounds of formula (1) may be formulated as lozenges comprising active ingredient in a flavored base, usually sucrose and acacia or tragacanth; pastilles comprising the active ingredient in an inert base such as gelatin and glycerin or sucrose and acacia; and mouthwashes comprising the active ingredient in a suitable liquid carrier.

For vaginal administration the formulations may be presented as pessaries, tampons, creams, gels, pastes, foams or sprays containing in addition to the active ingredient such carriers as are known in the art to be appropriate.

For rectal administration, unit dose suppositories wherein the carrier is a solid are preferred. Suitable carriers include cocoa butter and other materials commonly used in the art, and the suppositories may be conveniently formed by admixture of the active compound with the softened or melted carrier(s) followed by chilling and shaping in moulds.

For administration to the respiratory tract (including intranasal administration) compounds of formula (1) may be administered by any of the methods and formulations employed in the art for administration to the respiratory tract.

Thus in general the compounds of formula (1) may be administered in the form of a solution or a suspension or as a dry powder.

Solutions and suspensions will preferably be aqueous for example prepared from water alone (for example sterile or pyrogen-free water) or water and a physiologically acceptable co-solvent (for example ethanol, propylene glycol, and polyethylene glycols such as PEG 400).

Such solutions or suspensions may additionally contain other excipients for example preservatives (such as benzalkonium chloride), solubilising agents/surfactants such as polysorbates (e.g. Tween 80, Span 80, benzalkonium chloride), buffers, isotonicity-adjusting agents (for example sodium chloride), absorption enhancers and viscosity enhancers. Suspensions may additionally contain suspending agents (for example microcrystalline cellulose, carboxymethyl cellulose sodium).

Solutions or suspensions are applied directly to the nasal cavity by conventional means, for example with a dropper, pipette or spray. The formulations may be provided in single or multi-dose form. In the latter case a means of dose metering is desirably provided. In the case of a dropper or pipette this may be achieved by the patient administering an appropriate, predetermined volume of the solution or suspension. In the case of a spray this may be achieved for example by means of a metering atomizing spray pump.

An aerosol formulation may also be used for the respiratory tract administration, in which the compounds of formula (1) are provided in a pressurized pack with a suitable propellant such as a chlorofluorocarbon (CFC) for example dichlorodifluoromethane, trichlorofluoromethane or dichlorotetrafluoroethane, carbon dioxide or other suitable gas. The aerosol may conveniently also contain a surfactant such as lecithin. The dose of drug may be controlled by provision of a metered valve.

Alternatively the compounds of formula (1) may be provided in the form of a dry powder, for example a powder mix of the compound in a suitable powder base such as lactose, starch, starch derivatives such as hydroxypropylmethyl cellulose and polyvinylpyrrolidine (PVP). Conveniently the powder carrier will form a gel in the nasal cavity. The powder composition may

be presented in unit dose form for example in capsules or cartridges of e.g. gelatin or blister packs from which the powder may be administered by means of an inhaler.

In formulations intended for administration to the respiratory tract, including intranasal formulations, the compound will generally have a small particle size for example of the order of 5 microns or less. Such a particle size may be obtained by means known in the art, for example by micronisation.

For administration to the gastrointestinal tract, the compounds of formula (1) or a pharmaceutically acceptable derivative may be administered by any of the methods and formulations employed in the art for administration to the gastrointestinal tract.

When desired, formulations adapted to give sustained release of the active ingredient may be employed.

The compounds of formula (1) may also be used in combination with other therapeutic agents, for example anti-diabetic agents such as insulin, IGF, or analgesics, anti-hypertensive agents, sedatives, hypnotics, lipid-lowering agents, anti-infective agents and so on. The invention thus provides in a further aspect a combination comprising the compounds of formula (1) or a pharmaceutically acceptable derivative thereof together with another therapeutically active agent.

The combinations mentioned above may conveniently be presented for use in the form of a pharmaceutical formulation and thus such formulations comprising a combination as defined above together with a pharmaceutically acceptable carrier therefore comprise a further aspect of the invention.

The individual components of such combinations may be administered either sequentially or simultaneously in separate or combined pharmaceutical formulations.

When the compounds of formula (1) are used with a second therapeutic agent active in treatment of diabetes and related conditions, the dose of each compound may either be the same as or differ from that employed when each compound is used alone. Appropriate doses will be readily appreciated by those skilled in the art.

The compounds of formula (1) and their pharmaceutically acceptable derivatives may be prepared by any methods known in the art for the preparation of compounds of analogous structure.

The present invention is further described by the following examples, which are for illustrative purpose only and should not be construed as a limitation of the invention.

Example 1. Fermentation, isolation and purification of Gibberellins.

(a) Fermentation: Gibberellin A_3, A_4 and A_7 producing strain Gibberella fujikuroi was inoculated and grown in a medium containing 100g glucose, 100g sucrose, 2.5g NH_4NO_3, 0.25g KH_2PO_4, 0.2g $MgSO_4$, 0.01g $FeSO_4 \cdot 7H_2O$, 0.03g $ZnSO_4 \cdot 7H_2O$, 0.1g KCl, 10g peptone, 3g $CaCO_3$, 1000ml H_2O, at 28°C for 3~4 days. It was then transferred into a production medium containing 1000g glucose, 100g peptone, 24g NH_4NO_3, 100g KH_2PO_4, 20g $MgSO_4 \cdot 7H_2O$, 20g $FeSO_4 \cdot 7H_2O$, 1.5g $Na_2B_4O_7.10H_2O$, 8g $CuSO_4 \cdot 7H_2O$, 0.7g $(NH_4)_6Mo_7O_{24} \cdot 4H_2O$, 20 liter H_2O, at pH 4.5 at 28°C for 8~10 days. When the production of Gibberellins reached to peak (~3000μg/ml broth), the fermentation was stopped.

(b) Isolation: The fermentation broth (18 liter) was adjusted to pH 6.5~7.0 with 10% NaOH, then filtered off. The filter-cake (mycelium) was washed with 4L of H_2O. The filtrate and washings were combined and vacuum evaporated to a volume of 2L. The concentrate was stirred at 5~10°C with ethyl acetate (5L) and adjusted to pH 1.5 with 6NHCl. Then two layers were separated. The lower aqueous layer was re-extracted with ethyl acetate (2L). The

evaporated to 400ml. The concentrate was stirred and heated at 60~70°C for 3~4 hours until no more precipitation occurred. After cooling to room temperature, the suspension was filtered. The solid was washed with cold ethyl acetate and dried to afford Gibberellin A_3 and A_4/A_7 mixture as an off-white solid (45g). This mixture contains ~80% A_3, ~4% A_4 and ~4% A_7.

(c) Purification: 10g of the mixture of Gibberellin A_3 and A_4/A_7, as mentioned above, was dissolved in a mixture of 15ml methanol containing 1ml H_2O, and 30ml acetone. The solution was diluted with 100ml ethyl acetate containing 10ml of H_2O. The mixture was filtered. The filtrate was vacuum evaporated to a volume of about 80ml. The mixture was stirred and heated at 60~80°C for 2~3 hours, then cooled to room temperature. It was filtered off. The solid was washed with cold ethyl acetate and dried to afford Gibberellin A_3 at >95% purity as a white crystal (6.3g).
MS: 391 $(M-1+2Na)^+$ 369 $(M+23)^+$ 329 $(M+1-H_2O)^+$

Example 2. Preparation of Gibberellin A_3 salts and esters.

(a) Preparation of Gibberellin A_3 sodium salt: A solution of 346mg (1mmole) of Gibberellin A_3 was dissolved in 1.5ml of methanol, was added to a solution of $NaHCO_3$ (84mg, 1mmole) in 2ml H_2O. The whole mixture was evaporated under reduced pressure to dryness. The residue was then dissolved in water (2ml) and freeze dried to afford Gibberellin A_3 sodium salt was a white solid at quantitative yield.

(b) Preparation of Gibberellin A_3 zinc salt: 100mg of Gibberellin A_3 sodium salt was dissolved in 10ml water, then passed through a column (20ml) Dowex 50 Zinc ion form resin. The column was then washed with 30ml H_2O. The effluent and washings were combined and vacuum evaporated to small volume, then freeze dried to afford Gibberellin A_3 zinc salt as a white solid at quantitative yield.

(c) Preparation of Gibberellin A_3 ethyl ester: 346mg (1mmole) of Gibberellin A_3 was dissolved in a mixture of acetone (10ml) and water (0.2ml). To the

mixture at -20°C, triethylamine (100mg, 1mmole), N-methyl morpholine (10mg, 0.1mmole), ethyl chloroformate (108mg, 1mmole) were added. The mixture was stirred at –15°C for 20 minutes, then diluted with anhydrous ethanol (10ml). The mixture was stirred at room temperature overnight, then evaporated to dryness. The residue was then partitioned between ethyl acetate (30ml) and water (5ml). The organic layer was separated and washed successively with 2% HCl (5ml), water (5ml), 5% $NaHCO_3$ (5ml x 2), water (5ml), then evaporated under reduced pressure to dryness to afford a colorless solid Gibberellin A_3 ethyl ester (319mg, 85%) MS 375 $(M+1)^+$.

Example 3.

(a) Effect of Gibberellin A_3 on cell growth compared to EGF in vitro.

Human skin cell culture experiments were conducted by using keratinocytes media. Each well was seeded with 1,500 cells. Incubation was carried out at 37°C for a period of five days. The experiments are shown as follows:

Experiment	Media	Results
3.1	Perfect keratinocyte medium (containing EGF)	Very good growth (cell division rate = 100)
3.2	Perfect keratinocyte medium (containing EGF) plus Gibberellin A_3 (5µg/ml)	Very good growth (cell division rate = 100)
3.3	Keratinocyte medium containing no EGF	Poor growth
3.4	Keratinocyte medium containing no EGF, but containing Gibberellin A_3 (5µg/ml)	Very good growth (cell division rate ≈ 100)

Experiments 3.1 and 3.3 indicated that EGF (Epidermal Growth Factor) is essential for cell growth. Experiment 2 indicated that the presence of both EGF and Gibberellin A_3 had no additive effect on the rate of cell growth. Experiment 4 gave an indication that Gibberellin A_3 alone can stimulate cell growth as effectively as EGF.

(b) Effect of Gibberellin A_3 compared to IGF on cell culture growth using IGF-1 replace the EGF for the cell culture experiment, mentioned in (a). The results were similar to the results in (a).

Example 4.

The effect of a mixture of Gibberellin A_3 with Gibberellins A_4 and/or A_7 was compared to that of IGF-1 on the cell growth in vitro. The results were similar to those in example 3(b).

Example 5. Effect of Gibberellin A_3 on diabetic rats.

Methods:

Male Wistar rats (290g~330g) were weighed and lightly anaesthetized (4% halothane, 2:1 O_2/N_2O) so that blood glucose levels could be measured via a tail vein sample, using a Precision Q.I.D. glucometer. Diabetes was then induced by a single tail vein injection of streptozotocin (STZ, 60mg/kg), which was dissolved immediately prior to use in citrate buffer (50mM citric acid and 50mM trisodium citrate; pH 4.5). An equivalent volume of citrate buffer was injected into age-matched control rats.

Rats were housed in groups of two during the experiment. Animal house temperature was maintained at 20°C (±2°C) with a 12 hour light/dark cycle, and rats were allowed free access to food and water.

Ethical approval for all experiments was obtained from the Pharmacology Animal Ethics Committee.

Drug Administration and Daily Monitoring Protocol:

Forty-eight hours after the administration of STZ (60mg/kg), a blood glucose sample was taken and animals with blood glucose levels ≥16mM were considered to be diabetic. Rats were then randomly divided into groups.

The slow-acting, Lente Monotard insulin was used and Gibberellin sodium salt was made up as required in distilled water immediately prior to use.

Blood glucose readings were obtained two hours or 5 hours after the administration of drug(s) every three days. The results are shown as follows:

Group No.	Administered daily	Blood glucose level (mM) after day 20th		Body weight change on the 30th day
		2 hours	5 hours	
1	Insulin 4 unit/rat (sub-cutaneous)	4~5	3~5	+8%
2	Insulin 2 unit/rat (sub-cutaneous.)	15~18	14~16	-8%

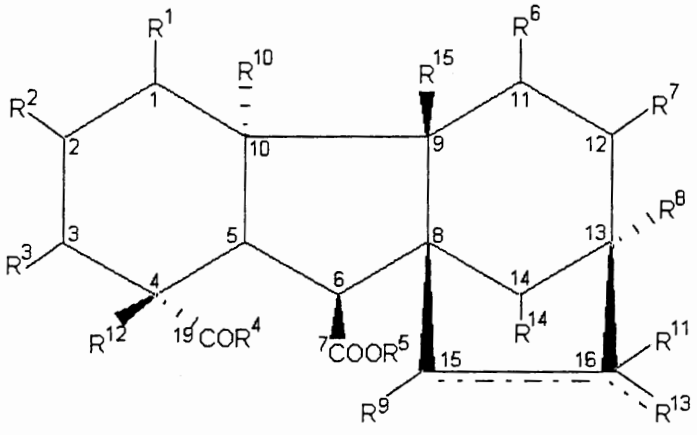
3	Gibberellin A_3 5mg/kg (sub-cutaneous) + 2 unit insulin/rat (sub-cutaneous)	4~6	N.A.	+10%
4	Gibberellin A_3 5mg/kg (intraperitoneal) + 2 unit insulin/rat (sub-cutaneous)	4~5	4~6	+12%
5	Gibberellin A_3 5mg/kg (oral) + 2 unit insulin/rat (sub-cutaneous.)	N.A.	4~6	+10%

Example 6. Effect of Gibberellin A_3 and A_4/A_7 mixture on diabetic rats.

The protocol of this experiment is the same as that in Example 5 but Gibberellin A_3 and A_4/A_7 mixture was used instead of Gibberellin A_3. The results were no different from those in Example 5.

CLAIMS:

1. Use of compounds of Formula (1) (Gibberellins)



Formula (1)

wherein

R^1 is H or a group –O-R^{20}, where R^{20} is H, a glycosylic ether group (glycoside ether), C_{1-6} alkyl group, or R^1 together with R^2 or R^{10} forms a bond (C_1– C_2 or C_1-C_{10} double bond, respectively);

R^2 is H or a group –O-R^{21}, where R^{21} is H, a glycosylic ether group (glycoside ether), or together with R^4 forms a bond (lactone) or R^2 together with R^1 or R^3 forms a bond (C_1-C_2 or C_2-C_3 double bond, respectively);

R^3 is H, =O, or –O-R^{22}, where R^{22} is H or a glycosylic ether group (glycoside ether), or R^3 together with R^2 forms a bond (C_2-C_3 double bond);

R^4 is OH, or –OR^{23}, where R^{23} is unsubstituted or substituted C_{1-20} alkyl, allyl, aryl, arylalkyl, amidine, -N$R^{24}R^{25}$ or an unsaturated or saturated ring containing one or more hetero-atoms selected from the group consisting of nitrogen, oxygen and sulfur; R^{24} and R^{25} may or may not be the same, are hydrogen, or C_{1-20} alkyl, allyl, aryl, arylalkyl or an unsaturated or saturated ring containing one or more hetero-

atoms selected from the group consisting of nitrogen, oxygen and sulphur; or R^4 together with R^{21} or R^{28} forms a bond (lactone);

R^5 is H or a glycosylic ester (glycoside ester) group, or unsubstituted or substituted C_{1-20} alkyl esters, allyl esters, aryl esters, arylalkyl esters, active esters;

R^6 is H or OH or together with R^7 forms a bond (C_{11}-C_{12} double bond);

R^7 is H, =O, or $-OR^{26}$, where R^{26} is H or a glycosylic ether group (glycoside ether) or R^7 together with R^6 forms a bond (C_{11}-C_{12} double bond);

R^8 is H, hydroxyl, mercaptan, or halogen, amino, azido, $NR^{24}R^{25}$, unsubstituted or substituted C_{1-20} alkyl, allyl, aryl, or arylalkyl, or $-OR^{27}$, where R^{27} is a glycosylic ether group (glycoside ether);

R^9 is H or OH, or together with R^{15} forms a bond (C_9-C_{15} bond);

R^{10} is H, CH_3, CHO, COOH, or a glycosylic ester (glycoside ester) of said COOH, CH_2O-R^{28} or $-OR^{28}$, where R^{28} is H or together with R^4 forms a bond (lactone) or R^{10} together with R^1 forms a bond (C_1-C_{10} double bond);

R^{11} is H, or OH or is absent;

R^{12} is CH_3, CH_2OH, COOH or a glycosylic ester (glycoside ester) of said COOH;

R^{13} is methylene, or a divalent hetero-atom, or NR^{29}, where R^{29} is NHR^{30} or OR^{30} where R^{30} is H, or C_{1-20} alkyl, aryl, alkylaryl; and a double bond is present between C_{16} and R^{13} when R^{11} is absent; or R^{13} is H, OH, CH_3 CHO, CH_2X, where X is halogen, $CHNR^{29}$ where R^{29} is NHR^{30} or OR^{30} where R^{30} is H, or C_{1-20} alkyl, aryl, alkylaryl when R^{11} is H or OH; with the proviso that where R^{11} is OH, R^{13} is not OH;

R^{14} is H or OH;

R^{15} is H, or together with R^9 forms a bond (C_9-C_{15} bond);

and/or pharmaceutically acceptable derivatives, including lactones, glycosides, esters, active esters and salts thereof in the manufacture of an anti-diabetic agent for use in the treatment of diabetes and its complications and associated conditions.

2. Use of compounds according to claim 1 wherein the complications and associated conditions of diabetes are one or more of: obesity, micro and macro vascular diseases, nephropathy, neuropathy, eye diseases, and diabetic ulcerations.

3. Use of compounds according to claim 1, wherein the Gibberellins are Gibberellin A_3.

4. Use of compounds according to claim 1, wherein the Gibberellins are a mixture of Gibberellin A_3 and Gibberellin A_4 and/or Gibberellin A_7.

5. Use of compounds according to claim 1, wherein the pharmaceutically acceptable derivatives are salts including alkali metal salts, alkaline earth metal salts, metal, and salts of ammonium, or organic bases.

6. Use of compounds according to claim 5, wherein the organic bases are lidocaine, or $NR^{16}\ R^{17}\ R^{18}\ R^{19}$, where R^{16}, R^{17}, R^{18}, R^{19}, which may be the same or not the same, are hydrogen, or substituted or unsubstituted C_{1-20} alkyl, alkanol, or aryl groups.

7. Use of compounds according to claim 1, wherein the pharmaceutically acceptable derivatives are lactones, glycosides, or esters and active esters.

8. Use of compounds of formula (1) (Gibberellins) or their pharmaceutically acceptable derivatives in the manufacture of an anti-diabetic agent for use in the treatment of diabetes and its complications and associated conditions wherein the medicament also contains substances selected from the group consisting of insulin, its fragment derivatives, IGFs, growth factors, and other pharmaceutically compatible anti-diabetic agents, or combinations thereof.

9. Use of compounds of formula (1) (Gibberellins) or their pharmaceutically acceptable derivatives in the manufacture of an anti-diabetic agent for use in the treatment of diabetes and its complications and associated conditions wherein the medicament also contains compatible therapeutic agents selected from the group consisting of analgesics, anti-hypertensive agents, sedatives, hypnotics, lipid-lowering agents, and anti-infective agents or combinations thereof.

10. Use of compounds according to claim 1, for the manufacture of an anti-diabetic agent for use in the treatment of type 1 diabetes and its related conditions.

11. Use of compounds according to claim 1, for the manufacture of an anti-diabetic agent for use in the treatment of type 2 diabetes and its related conditions.

12. Use of compounds according to claim 1, for the manufacture of an anti-diabetic agent for use in the treatment of insulin resistant diabetes.

13. Use of compounds according to claim 1, for the manufacture of an anti-diabetic agent for use in the treatment of diabetic related complications and associated conditions, namely obesity, micro and macro vascular diseases, nephropathy, neuropathy and eye diseases.

14. An anti-diabetic agent comprising a compound of formula (1) and/or its derivatives as an active ingredient, together with a pharmaceutically acceptable carrier.

15. An anti-diabetic agent according to claim 14, wherein the agent is a medicament suitable for administration with a medicator.

16. An anti-diabetic agent comprising a compound of formula (1) as an active ingredient, together with pharmaceutically acceptable carriers or excipients, wherein the agent is a slow release composition.

17. An anti-diabetic agent according to claim 14, wherein the agent is for oral administration.

18. An anti-diabetic agent according to claim 14, wherein the agent is for inhalation administration.

19. An anti-diabetic agent according to claim 14, wherein the agent is for transdermal administration.

20. An anti-diabetic agent according to claim 14, wherein the agent is for parenteral injection.

21. An anti-diabetic agent according to claim 14, wherein the agent is for topical, rectal, or vaginal administration.

22. An anti-diabetic agent according to any one of claims 14, 15 or 16, wherein the derivative of formula (1) is selected from the group consisting of lactones, esters, alkali metal salts, alkaline earth metal salts, transition metal salts, ammonium salts and organic bases.

23. An anti-diabetic agent according to claim 22 wherein the derivative is a sodium salt of formula (1).

24 An anti-diabetic agent according to claim 22 wherein the derivative is a zinc salt of formula (1).

25. An anti-diabetic agent according to claim 22 wherein the derivative is a ethyl ester of formula (1).

26. A method of manufacturing an anti-diabetic agent according to claim 14, comprising combining a compound of formula (1) and/or its derivatives with a pharmaceutically acceptable carrier.

27. A process for the preparation of Gibberellins including Gibberellin A_3, including the steps of:

(a) incubating a Gibberellin-producing strain of microorganism in a fermentation broth;

(b) adjusting the pH of the fermentation broth to pH 6.5 to 7.0 and filtering to obtain a filter cake of microorganism mycelium, and a filtrate;

(c) washing the filter cake with water and combining the washing with the filtrate to form an aqueous solution;

(d) concentrating the aqueous solution;

(e) mixing the aqueous solution with an organic solvent at a temperature of 5 to 10°C and adjusting the pH of the mixture to less than 2.0;

(f) allowing the mixture to separate into an aqueous phase and a first organic phase and removing the first organic phase;

(g) re-extracting the aqueous phase from step (f) with organic solvent to obtain a second organic phase;

(h) combining the first and second organic phases and concentrating to form a concentrated organic solution;

(i) heating the concentrated organic solution at 60-70°C for 3 to 4 hours with stirring, until the precipitation of solid matter ceases;

(j) cooling the concentrated organic solution to room temperature and filtering to obtain a precipitate;

(k) washing the precipitate in cold organic solvent and drying to obtain an off-white solid containing about 80% Gibberellin A_3, about 4% Gibberellin A_4 and about 4% Gibberellin A_7.

28. The process of claim 27, comprising the further steps of:

(l) dissolving the off-white solid in a mixture of 32.6% methanol, 2.2% water and 65.2% acetone to obtain a Gibberellin solution;

(m) diluting the Gibberellin solution with a 10:1 mixture of organic solvent and water;

(n) filtering the diluted Gibberellin solution and concentrating the filtrate by vacuum evaporation;

(o) heating the concentrate to a temperature of 60 to 80°C for 2 to 3 hours with stirring , cooling to room temperature and filtering to obtain a solid crystalline precipitate;

(p) washing the precipitate with cold organic solvent and drying to obtain Gibberellin A_3 crystals.

29. A process according to claim 31 wherein the Gibberellin-producing strain of microorganism is *Gibberella fujikuroi.*

30. A process according to claim 27, wherein the concentration of the solutions in steps (d) and (h) is achieved using vacuum evaporation.

31. A process according to claim 31 wherein the organic solvent is ethyl acetate.

32. A process according to claim 32 wherein the organic solvent is ethyl acetate.

33. A process according to claim 32 comprising the further steps of:

(q) dissolving the Gibberellin A_3 in methanol;

(r) adding the Gibberellin solution to an equimolar aqueous solution of $NaHCO_3$;

(s) evaporating the mixed solutions to dryness to obtain a solid residue;

(t) dissolving the residue in water and freeze drying to obtain Gibberellin A_3 sodium salt.

34. A process according to claim 33, comprising the further steps of dissolving the Gibberellin A_3 sodium salt in water, passing the solution through a column loaded with a zinc ion-exchange resin, washing the column with water, collecting and combining the effluent and washings and removing the water to obtain Gibberellin A_3 zinc salt.

35. A process according to claim 28 comprising the further steps of:

(q) dissolving the Gibberellin A_3 in a 50:1 ratio mixture of acetone to water;

(r) mixing the Gibberellin A_3 solution with equimolar amounts of triethylamine and ethyl chloroformate, and a one tenth molar amount of N-methyl morpholine, and stirring at -15°C for 20 minutes;

(s) diluting the resultant mixture with anhydrous ethanol and stirring at room temperature;

(t) evaporating the diluted mixture to dryness and partitioning the residue between ethyl acetate and water in a 6:1 ratio;

(u) separating the ethyl acetate layer, washing with 2% HCl, followed by water, followed by 5% $NaHCO_3$, followed by water, and evaporating under reduced pressure to dryness to give Gibberellin A_3 ethyl ester.