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(RESEARCH ARTICLE)



## Prevention and control of diabetes by intake of succulent biomedicines and following of designed lifestyle: A ready plan for execution

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### Abstract

**Background:** Diabetes is an important disease without any available medicine to cure it. Lifestyle is having some strong roles in the initiation and progression of the disease. Plant resources are so far studied to get effective medicines for that disease only in their dry state, either directly or on the diluents-extracted sections to identify the active principles to synthesize marketable drugs, but achieved very limited success. The anti-diabetic medicinal plants contain a huge number of phyto-constituents at their succulent stage, all of which can work together when used unaltered for this purpose.

**Methods:** Identification of commonly used anti-diabetic plants from previous reports was targeted to find out a few plants with strong potency for their use as some succulent biomedicines against diabetes. Standardization of a layout for the production of such medicines from these plants was attempted along with a listing of the lifestyle-related factors of diabetes.

**Result:** The succulent plant materials can be encapsulated inside bio-encapsulating materials with bio-preservatives following the standard techniques of drug development with some modifications and can be transported to the patients under a cold chain. A brief list of reported anti-diabetic medicinal plants is added and forty plants are selected for the production of anti-diabetic biomedicines. The layout of all the related techniques is added. The lifestyle-related factors are identified and scopes for their modification are discussed.

**Conclusion:** Triggering of the genetic predisposition for diabetes can be prevented and the severity of the disease can be minimized by incurring some modification in lifestyle and intake of some succulent biomedicine capsules.

**Keywords:** Diabetes; Herbal therapy; Anti-diabetic plants; Succulent biomedicines; Lifestyle modification

### 1. Introduction

Diabetes or hyperglycemia is a physical condition that causes a rise in glucose levels in the blood higher than normal [1,2]. The number of people suffering from diabetes is increasing at a very rapid rate. In type 1 diabetes, children are developing autoantibodies against beta cells of the pancreas and develop diabetes for the destruction of these insulin-producing cells of the pancreas. Activities of some viruses or some toxic chemicals entered into the body through food are supposed to act behind such triggering of genes responsible for autoantibody development. Reasons for the development of gestational diabetes are very much debated, but the influence of both genetic and lifestyle factors are also acting there [2]. Among the three main types of diabetes (Type 1 or childhood, type 2, and gestational), type 2 diabetes (t2d) is of most concern, and most of the global research is performed to prevent or manage that form of

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diabetes. It is estimated that 439 million people around the globe would have t2d out of a total of 552 million diabetic patients in 2030 [1].

The glucose obtained from the ingested foods and drinks is absorbed in the blood. It is utilized as the source of energy by the tissues of the body with the assistance of insulin, secreted by the pancreas. In t2d, the insulin-sensitive cells fail to respond appropriately to insulin. It is also termed insulin resistance. So, the sugar level in the blood rises continuously. The body wants to overcome the situation by secreting more insulin. After a certain stage, this effort fails to control the situation and a continuously high level of glucose in the blood brings many serious detrimental effects on health.

Among the various harmful health effects of high glucose levels in the blood for a long period, an increase in the risk of heart attack, initiation and rapid progression of different kidney diseases, blindness, nerve pain, and becoming more prone to infections are the problems of most important category [3,4,5].

The exact causes behind the development of t2d are not clear. Several risk factors are linked with the development of the disease among individuals. The risk factors are different combinations of genetic, metabolic, and environmental factors interacting with one another to bring the outcome. Family history, genetic predisposition, sedentary or irregular lifestyle, mental stress, unhealthy diet, obesity, high blood pressure and its medication, low HDL (high-density cholesterol) and high triglyceride level in the blood, diseases like PCOD in females (Polycystic ovarian disease), higher age, etc. are the main influencing parameters [1,6]. The imbalance between requirement and supply of different nutritional factors, level of physical activity, gut dysbiosis, metabolic memory of previous hyperglycemia, mitochondrial dysfunction, etc. are recently identified as some other factors acting behind the development of t2d [5].

No cure for t2d has yet been found possible by the use of drugs. The main targets of the contemporary anti-diabetic medication include stimulation of beta cells of the pancreas in different ways to secrete more insulin, stimulation of sensitivity of the tissues for uptake and use of sugar (bypassing of insulin resistance), reduction in the rate of generation of sugar from stored sugar (glycogen), protein or fat in the liver; a decrease of the breakdown of complex carbohydrate as well as reduction of absorption of sugar from the small intestine, increase in urinary glucose excretion, etc. or a combination of such approaches [1,7,8].

Various pharmacological preparations (mainly chemicals of synthetic origin) are used to control the situation. These include Biguanides (Metformin), Sulfonylureas (Glipizide, Glimepiride, Glyburide, etc.), Thiazolidinediones (Pioglitazone), Alpha-glucosidase inhibitors (Miglitol, Acarbose), Non-sulfonylurea insulin secretagogues (Nateglinide, Repaglinide), Sodium-glucose cotransporter 2 (SGLT2) Inhibitors (Dapagliflozin, Canagliflozin, Empagliflozin), DPP4 Inhibitors (Alogliptin, Sitagliptin, Linagliptin, Saxagliptin), Incretin mimetic (Liraglutide, Exenatide, Dulaglutide, Lixisenatide, Albiglutide), Amylinomimetic (Pramlintide), Rapid-acting insulins (Aspart, Lispro, Glulisine, Insulin human), Short-acting insulins (Regular, NPH), Intermediate-acting insulin (Detemir), Long-acting insulins (Degludec, Glargine, etc.) [9]. But a regular increase of the dose of these medicines is required and many of these medicines have many serious side effects, particularly in higher doses and continuous long-term use. The continuous expenditure on diagnosis and treatment of diabetes and its various complications is not easily bearable by many people, particularly middle or low-income groups of people worldwide [10].

There are reports of the use of many plant materials in the management of hyperglycemia. Many of these are considered non-toxic or very less toxic to our health [11,12].

There are about 800 plants reported of having antidiabetic potential. A wide collection of various plant-derived bioactive compounds (active principles) have already established their role in the prevention and treatment of diabetes in various laboratory studies, though not been found suitable for therapeutic use [13,14].

The attributed anti-hyperglycemic effects of the reported plants may be due to their ability to restore the function of pancreatic tissues and cause an increase in insulin output, modulation of sensitivity of the tissues to use glucose, and causing a decrease in the intestinal absorption of glucose, etc. So, the effects of giving protection to the  $\beta$ -cells of the pancreas along with regulation of the fluctuation in glucose levels inside the body can act together during the use of the anti-diabetic herbal medicines [11].

Use of the succulent biomedicines to control and combat various diseases of infectious and non-infectious origin is a novel concept [15,16,17]. The living plant engages in various metabolic activities and the succulent parts of the plants (fruit, stem, leaf, root, etc.) contain a huge number of phytochemicals, all of which act together but all may not be detectable individually by the available modern tools and techniques [18,19,20].

Various parts of the medicinal plants contain many such unidentifiable components in their succulent stages which may play some very important roles during acting cumulatively. The present concept of the use of dry parts of medicinal plants (in Ayurveda or alike codified herbal medicines), through alcoholic extracts (Homoeopathy), through identification of active principles by studying the extracts of the powdered dry parts and obtained by using chemical diluents and performing laboratory synthesis of such principles (Modern medicine) – all are having limitation of not getting the lost principles available in their succulent state and absence of cumulative effects of all such principles to incur the desired effects [19,21,22].

The ancient problems of all-season unavailability of the living medicinal plants, spoilage of succulent plant parts during storage, etc. are not at all relevant at present time, as we are having good alternatives [19,20,21].

Like original fruit pulps, fruit juice, etc., and many other true herbal cosmetics and healthcare products can be made available to the patients and consumers without the addition of any synthetic chemicals like preservatives following the novel technique of bio-encapsulation with cold chain transport of the items [17,21]. So, some very good alternatives to sugar-added food items like bottled fruit juice or ice creams, etc. are available that don't supply any synthetic chemicals and extra sugar to our body.

The technique of use of succulent parts of plants directly as some medicines is having an immense potency to convert the present disease creation, disease diagnosis by various diagnostics and then use of medicines to control or cure of it to a new technique of disease prevention and incurring disease resistance power among the people, which can ultimately create a world with only a few diseases and with a requirement of only a few medicines of synthetic origin [16,19,20]. A model application of this technique may be the use of succulent biomedicines for the control of diabetes.

The present study is designed with the objectives of listing some reported medicinal plants commonly named for anti-diabetic activities and preparation of a layout for the production of anti-diabetic succulent biomedicine capsules from the medicinal parts of some of such plants without the addition of any synthetic chemical and their transportation up to the patient level throughout the globe. Identification of different lifestyle factors influencing the initiation and progression of diabetes are explored to identify the ways to stay outside of their influence.

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## **2. Material and methods**

### **2.1 Pants used for anti-diabetic effects**

The genetic predisposition or family history for the development of t2d requires some triggering factors for its physical expression. On the contrary, masking of genetic predisposition can also be performed by lifestyle modification, intake of only directed foods, and by use of succulent biomedicines. Many plants are used for their anti-diabetic effects. Some of these anti-diabetic plants can act as some preventive agents inside the body for the development of diabetes. Some others may act as a curative agent and in many cases; there is perhaps no clear-cut demarcation line in the activities of many of such plants.

A literature survey was planned to identify the commonly named plants for their anti-diabetic activities.

### **2.2 Selection of some plants for a model study for the production of anti-diabetic succulent biomedicines**

From the list of commonly stated anti-diabetic plants, a short listing of some plants was planned to use in the proposed pilot project for the development of anti-diabetic succulent biomedicines.

### **2.3 Preparation of anti-diabetic succulent biomedicines**

For the standardization of different steps and procedures related to the preparation of anti-diabetic biomedicines from the succulent parts of the selected medicinal plants, the following steps are important.

- Collection of materials
- Collection of cut pieces, pastes, juices from succulent plant parts, and powders from the dry seeds
- Validation of activities, the study of toxicity, determination of indication, doses, etc.
- Individual dosing of the medicines and their use
- Preservation and encapsulation of the succulent biomedicines
- Addition of spoilage indicator
- Freezing and transportation of the biomedicines up to the patients or consumers

- Special legislative control on the entire procedure.

## 2.4 Identification of lifestyle factors related to the prevention of diabetes

Different lifestyle factors are having a possible connection with the initiation and progression of diabetes. Identification and then removal of such risk factors can make prevention and treatment of the disease easier.

## 3. Results and discussion

### 3.1 Plants used for antidiabetic effects

Among the articles surveyed for anti-diabetic plants, Grover *et al.* (2002) described 15 plants [23], Malviya *et al.* (2010) - 21 plants [11], Goel *et al.* (2012) - 15 plants [24], Elavarasi *et al.* (2013) described 39 plants [10], Arumugam *et al.* (2013) - 33 plants [14], Rawat *et al.* (2013) - 20 plants [25], Patekar and Jaiswal (2017) - 18 plants [26], Moradi *et al.* (2018) - 30 plants [27], Yagi and Yagi (2018) - 38 plants [28], Mishra *et al.* (2019) - 40 such plants [12], etc.

A concise list of reported anti-diabetic plants is prepared from these sources and displayed in table 1.

**Table 1** A brief list of plants with report of anti-diabetic activities

Plant name with Family	Common Name	Parts used
<i>Abelmoschus esculentus</i> L. (Moench). [Malvaceae]	Ladies finger	Flower and fruit
<i>Abroma augustum</i> (L.) L.f. [Malvaceae]	Devil's cotton	Leaf
<i>Acacia arabica</i> (Lam.) Willd. [Fabaceae]	Acacia	Leaf, inner bark, pod
<i>Acacia senegal</i> (L.) Willd. [Fabaceae]	Sudan gum	Fruit
<i>Acanthopanax senticosus</i> (Rupr. & Maxim.) Harms [Araliaceae]	Siberian ginseng	Root, stem bark
<i>Achyranthes aspera</i> L. [Amaranthaceae]	Chaff flower	Leaf, root
<i>Acorus calamus</i> L. [Acoraceae]	Sweet flag	Rhizome
<i>Adansonia digitata</i> L. [Malvaceae]	African baobab	Stem bark
<i>Agrimonia eupatoria</i> L. [Rosaceae]	Stickwort	Aerial parts
<i>Alangium lamarckii</i> Thwaites [Cornaceae]	Sage-leaved alangium	Leaf
<i>Albizia odoratissima</i> (L.f.) Benth. [Fabaceae]	Black siris	Bark
<i>Allium cepa</i> L. [Amaryllidaceae]	Bulb Onion	Bulb
<i>Aloe sinkatana</i> Reynolds [Asphodelaceae]	Sudan Aloe	Leaf
<i>Aloe vera</i> (L.) Burm.f. [Asphodelaceae]	Indian Aloe	Leaf
<i>Ambrosia maritima</i> L. [Asteraceae]	Coastal Ragweed	Leaf
<i>Ammi visnaga</i> (L.) Lam. [Apiaceae]	Toothpick plant	Fruit
<i>Anacardium occidentale</i> L. [Anacardiaceae]	Cashew	Bark
<i>Ananas comosus</i> L. (Merr.) [Bromeliaceae]	Pineapple	Fruit, leaf
<i>Annona muricata</i> L. [Annonaceae]	Soursop	Leaf
<i>Annona squamosa</i> L. [Annonaceae]	Sugar apple	Leaf
<i>Areca catechu</i> L. [Arecaceae]	Betel tree	Nut
<i>Alstonia scholaris</i> (L.) R. Br [Apocynaceae]	Devil's tree	Bark
<i>Axonopus compressus</i> (Sw.) P. Beauv. [Poaceae]	Carpet grass	Leaf
<i>Bacopa monnieri</i> (L.) Pennell [Plantaginaceae]	Water hyssop	Leaf
<i>Balanites aegyptiaca</i> (L.) Del. [Zygophyllaceae]	Egyptian balsam	Fruit

<i>Bauhinia rufescens</i> Lam. [Fabaceae]	Silver butterfly	Leaf
<i>Bauhinia forficata</i> Link. [Fabaceae]	Brazilian orchid tree	Leaf
<i>Berberis aristata</i> DC. [Berberidaceae]	Indian barberry	Root
<i>Berberis vulgaris</i> L. [Berberidaceae]	Common barberry	Root
<i>Benincasa hispida</i> (Thunb.) Cogn. [Cucurbitaceae]	Wax gourd	Fruit
<i>Biophytum sensitivum</i> (L.) DC. [Oxalidaceae]	Little tree plant	Whole plant
<i>Boerhaavia diffusa</i> L. [Nyctaginaceae]	Red spiderling	Leaf, root
<i>Bougainvillea spectabilis</i> Willd. [Nyctaginaceae]	Great bougainvillea	Leaf
<i>Brassica juncea</i> (L.) Czern. [Brassicaceae]	Brown mustard	Seed
<i>Bridelia ndellensis</i> Beille. [Phyllanthaceae]	Yelimadu	Stem bark
<i>Bruguiera gymnorhiza</i> (L.) Lam. [Rhizophoraceae]	Oriental mangrove	Roots
<i>Butea monosperma</i> (Lam.) Taub. [Fabaceae]	Flame-of-the-forest	Flower
<i>Caesalpinia bonducella</i> (L.) Fleming NJJ [Fabaceae]	Nicker bean	Seed
<i>Caesalpinia digyna</i> Rottler [Fabaceae]	Teri pod	Root
<i>Cajanus cajan</i> (L.) Millsp. [Fabaceae]	Pigeon pea	Leaf
<i>Calotropis gigantea</i> (L.) Dryand. [Apocynaceae]	Crown flower	Leaves, flowers
<i>Canavalia ensiformis</i> (L.) DC. [Fabaceae]	Jack bean	Seed
<i>Capparis decidua</i> (Forssk.) Edgew. [Capparaceae]	Karira	Fruit, stem
<i>Caralluma sinaica</i> (Decaisne) A. Berger [Apocynaceae]	Kari	Root, aerial parts
<i>Carica papaya</i> L. [Caricaceae]	Papaya	Leaf
<i>Carthamus tinctorius</i> L. [Asteraceae]	Sunflower	Flower
<i>Casearia esculenta</i> Roxb. (Flacourtiaceae)	Dodda haniche	Root
<i>Cassia kleinii</i> Wight & Arn. [Caesalpinaceae]	Sickle Senna	Leaf
<i>Cassia auriculata</i> L. [Caesalpinaceae]	Matura tea tree	Flower
<i>Centaurium erythraea</i> Rafn [Gentianaceae]	Common centaury	Leaf
<i>Catunaregam nilotica</i> (Stapf) Tirven [Rubiaceae]	Chibra	Fruit
<i>Centella asiatica</i> (L.) Urb. [Apiaceae]	Indian pennywort	Leaf
<i>Chaenomeles sinensis</i> (Thouin) Koehne [Rosaceae]	Chinese quince	Fruit
<i>Cicer arietinum</i> L. [Fabaceae]	Chickpea	Seed
<i>Cichorium intybus</i> L. [Asteraceae]	Common chicory	Root, leaf
<i>Cinnamomum tamala</i> (Buch.-Ham.) T. Nees & C.H. Eberm [Lauraceae]	Indian bay leaf	Leaf
<i>Cocculus hirsutus</i> (L.) Diels [Menispermaceae]	Broom creeper	Leaf
<i>Cocos nucifera</i> L. [Arecaceae]	Coconut tree	Immature inflorescence, young spadix
<i>Combretum micranthum</i> G. Don [Combretaceae]	Kinkeliba	Leaf
<i>Coriandrum sativum</i> L. [Apiaceae]	Chinese parsley	Seed
<i>Coscinium fenestratum</i> Colebr. [Menispermaceae]	Yellow vine	Stem
<i>Costus speciosus</i> (J. Koenig) Sm. [Costaceae]	Crêpe ginger	Rhizome

<i>Cyclocarya paliurus</i> (Batalin) Iljinsk. [Juglandaceae]	Wheel wingnut	Leaf, Bark
<i>Cynodon dactylon</i> (L.) Pers. [Poaceae]	Bermuda grass	Aerial parts
<i>Dendrobium chrysotoxum</i> Lindl. [Orchidaceae]	Fried egg orchid	Aerial parts
<i>Dillenia indica</i> L. [Dilleniaceae]	Elephant apple	Leaf
<i>Dioscorea dumetorum</i> (Kunth) Pax [Dioscoreaceae]	Bitter yam	Tuber
<i>Dregea volubilis</i> (L. f.) Benth. ex Hook. f. [Apocynaceae]	Juktiphool	Flower
<i>Elephantopus scaber</i> L. [Asteraceae]	Elephant's Foot	Root, leaf
<i>Enicostemma littorale</i> Blume [Gentianaceae]	Chhota chirayata.	Whole plant
<i>Eucalyptus globulus</i> Labill. [Myrtaceae]	Southern blue gum	Leaf
<i>Faidherbia albida</i> (Delile) A. Chev. [Fabaceae]	Apple-ring acacia	Root bark
<i>Ferula assa-foetida</i> L. [Apiaceae]	Asafoetida	Resin
<i>Ficus benghalensis</i> L. [Moraceae]	Indian banyan	Stem bark
<i>Ficus hispida</i> L. [Moraceae]	Opposite leaf Fig	Leaf, fruit
<i>Ficus racemosa</i> L. [Moraceae]	Custer fig	Leaf, fruit
<i>Ficus religiosa</i> L. [Moraceae]	Sacred fig	Bark
<i>Geigeria alata</i> (Hochst. & Steud. ex DC.) Oliv. & Hiern [Asteraceae]	Geigeria	Root
<i>Glinus oppositifolius</i> (L.) Aug. DC. [Molluginaceae]	Bitter Leaf	Leaf
<i>Guazuma ulmifolia</i> Lam. [Malvaceae]	Bay cedar	Bark
<i>Guiera senegalensis</i> J. F. Gmel. [Combretaceae]	Guiera	Leaf
<i>Helicteres isora</i> L. [Malvaceae]	Indian screw tree	Fruit, root
<i>Hibiscus rosa sinensis</i> L. [Malvaceae]	China rose	Aerial parts, flower
<i>Holarrhena pubescens</i> Wall. ex G. Don [Apocyanaceae]	Indraja	Seed
<i>Hybanthus enneaspermus</i> L. (F. Muell.) [Violaceae]	Spade flower	Whole plant
<i>Hyphaene thebaica</i> (L.) Mart. [Arecaceae]	Doum palm	Fruit
<i>Ichnocarpus frutescens</i> (L.) W.T. Aiton [Apocyanaceae]	Black creeper	Leaf
<i>Ipomoea batatas</i> (L.) Lam. [Convolvulaceae]	Sweet potato	Leaf
<i>Jatropha curcas</i> L. [Euphorbiaceae]	Physic nut	Leaf
<i>Justicia adhatoda</i> L. [Acanthaceae]	Malabar nut	Leaf
<i>Kaempferia parviflora</i> Wall. ex Baker [Zingiberaceae]	Thai Ginseng	Root
<i>Khaya senegalensis</i> (Desr.) A. Juss. [Meliaceae]	Dry zone mahogany	Stem bark
<i>Kigelia africana</i> (Lam.) Benth [Bignoniaceae]	Sausage tree	Fruit
<i>Lantana camara</i> L. [Verbanaceae]	Common lantana	Leaf
<i>Lawsonia inermis</i> L. [Lythraceae]	Henna tree	Leaf
<i>Lippia nodiflora</i> (L.) Michx. [Verbenaceae]	Frog fruit	Whole plant
<i>Liriope spicata</i> (Thunb.) Lour. [Asparagaceae]	Monkey grass	Leaf
<i>Lupinus albus</i> L. Subsp. <i>termis</i> (Forsk.) Ponert. [Fabaceae]	White lupin	Fruit
<i>Mangifera indica</i> L. [Anacardiaceae]	Mango	Leaf
<i>Melia azedarach</i> L. [Meliaceae]	Chinaberry tree	Leaf

<i>Mitragyna inermis</i> (Willd.) Kuntze [Rubiaceae]	False abura	Fruit
<i>Mollugo pentaphylla</i> L. [Molluginaceae]	Five-leaved carpetweed	Leaf
<i>Momordica charantia</i> L. [Cucurbitaceae]	Bitter gourd	Fruit, leaf
<i>Marrubium vulgare</i> L. [Lamiaceae]	White horehound	Aerial part
<i>Morus alba</i> L. [Moraceae]	Common mulberry	Leaf
<i>Mucuna pruriens</i> (L.) DC. [Fabaceae]	Bengal velvet bean	Seed
<i>Murraya koenigii</i> (L.) Sprengel [Rutaceae]	Curry leaf tree	Leaf
<i>Musa paradisiaca</i> L. [Musaceae]	Hybrid banana	Inflorescence
<i>Musa sapientum</i> L. [Musaceae]	Banana	Inflorescence
<i>Nauclea latifolia</i> Smith [Rubiaceae]	Nauclea	Leaf
<i>Nigella sativa</i> L. [Ranunculaceae]	Black cumin	Seed
<i>Opuntia ficus-indica</i> (L.) Mill. [Cactaceae]	Indian fig opuntia	Leaf
<i>Opuntia streptacantha</i> Lam. [Cactaceae]	Prickly pear	Leaf
<i>Ophiopogon japonicus</i> (Thunb.) Ker Gawl. [Asparagaceae]	Fountain plant	Root
<i>Ougeinia oojeinensis</i> (Roxb.) Hochr. [Fabaceae]	Ujjain desmodium tree	Bark
<i>Panax ginseng</i> C. A. Mey. [Araliaceae]	Asian ginseng	Root
<i>Parinari excelsa</i> Sabine [Chrysobalanaceae]	Guinea plum	Bark
<i>Perilla frutescens</i> (L.) Britton [Lamiaceae]	Perilla	Leaf
<i>Phyllanthus reticulatus</i> Poir. [Phyllanthaceae]	Black-berried featherfoil	Leaf
<i>Polyalthia longifolia</i> (Sonn.) Thwaites [Annonaceae]	False ashoka	Bark
<i>Posidonia oceanica</i> (L.) Delile [Posidoniaceae]	Neptune grass	Leaf
<i>Prosopis glandulosa</i> Torr. [Fabaceae]	Honey mesquite	Whole plant
<i>Psidium guajava</i> L. [Myrtaceae]	Common guava	Unripe fruit peel
<i>Pterocarpus marsupium</i> Roxb. [Fabaceae]	Malabar kino	Bark
<i>Punica granatum</i> L. [Lythraceae]	Pomegranate	Fruit juice, leaf
<i>Rhynchosia minima</i> (L.) DC. [Fabaceae]	Jumby-bean	Root
<i>Ricinus communis</i> L. [Euphorbiaceae]	Castor oil plant	Leaf, root
<i>Rubia cordifolia</i> L. [Rubiaceae]	Indian madder	Root
<i>Rumex patientia</i> L. [Polygonaceae]	Patience dock	Seed, aerial part
<i>Salvadora oleoides</i> Decne [Salvadoraceae]	Bada Peelu	Aerial parts
<i>Salacia chinensis</i> L. [Celastraceae]	Lolly berry	Root
<i>Salacia macroperma</i> Wight [Celastraceae]	Aanakoranti	Root
<i>Salvia nemorosa</i> L. [Lamiaceae]	Woodland sage	Aerial part
<i>Salvia officinalis</i> L. [Lamiaceae]	Common sage	Leaf
<i>Saraca asoca</i> (Roxb.) Willd [Fabaceae]	Ashoka tree	Flower
<i>Sarcopoterium spinosum</i> (L.) Spach [Rosaceae]	Thorny burnet	Root
<i>Sclerocarya birrea</i> (A. Rich.) Hochst [Anacardiaceae]	Marula	Stem bark

<i>Securinega virosa</i> Roxb (Ex Willd) Baill. [Euphorbiaceae]	White Berry bush	Leaf
<i>Selaginella tamariscina</i> (P. Beauv.) Spring [Selaginellaceae]	White Tip Spikemoss	Whole plant
<i>Semecarpus anacardium</i> L.f. [Anacardiaceae]	Marking nut tree	Nut milk
<i>Senna auriculata</i> (L.) Roxb. [Fabaceae]	Matura tea tree	Leaf
<i>Senna obtusifolia</i> (L.) H.S. Irwin & Barneby [Fabaceae]	Sicklepod	Root, leaf
<i>Sesamum indicum</i> L. [Pedaliaceae]	Sesame	Seed
<i>Setaria italica</i> (L.) P. Beauvois [Poaceae]	Foxtail millet	Seed
<i>Sida cordifolia</i> L. [Malvaceae]	Flannel weed	Whole plant
<i>Smallanthus sonchifolius</i> (Poepp.) H. Rob. [Asteraceae]	Peruvian ground apple	Root
<i>Solanum torvum</i> Sw. [Solanaceae]	Devil's fig	Fruit
<i>Solanum xanthocarpum</i> Schrad. [Solanaceae]	Yellow-berried nightshade	Leaf
<i>Striga hermonthica</i> (Delile) Benth. [Orobanchaceae]	Purple witchweed	Whole plant
<i>Strychnos potatorum</i> L.f. [Loganiaceae]	Clearing-nut tree	Whole plant
<i>Symplocos coccinea</i> Humb. & Bonpl. [Symplocaceae]	Limoncillo	Seed and leaf
<i>Symplocos cochinchinensis</i> (Lour.) S. Moore [Symplocaceae]	Laurel sapphire berry	Leaf
<i>Swertia punicea</i> Hemsl. [Gentianaceae]	Ganyancao	Whole plant
<i>Terminalia bellirica</i> (Gaertn.) Roxb. [Combretaceae]	Baheda	Fruits
<i>Terminalia catappa</i> L. [Combretaceae]	Indian almond	Leaf, bark, fruit
<i>Tinospora bakis</i> (A.Rich.) Miers [Menispermaceae]	Abolo	Seed
<i>Urtica dioica</i> L. [Urticaceae]	Common nettle	Leaf
<i>Vaccinium bracteatum</i> Thunb. [Ericaceae]	Asiatic bilberry	Leaf
<i>Vangueria madagascariensis</i> J.F. Gmel. [Rubiaceae]	Spanish-tamarind	Fruit, leaf
<i>Vernonia anthelmintica</i> (L.) Willd. [Asteraceae]	Ironweed.	Seed
<i>Vitex negundo</i> L. [Lamiaceae]	Five-leaved chaste tree	Leaf
<i>Viscum schimperi</i> Engl. [Viscaceae]	Soudi mistletoe	Aerial parts
<i>Wrightia antidysenterica</i> (L.) R. Br. [Apocynaceae]	Coral swirl	Seed
<i>Zygophyllum album</i> L.f. [Zygophyllaceae]	Lescol	Whole plant
<i>Zygophyllum coccineum</i> L. [Zygophyllaceae]	Scarlet-flowered bean-caper	Aerial part

### 3.2 Selection of the medicinal plants

Many plants are having reported activities against the development and/or cure of t2d. Among these plants, some plants are well known to the research communities for years and also many of these are already in use by people for different purposes. Considering these related factors, a total of 40 (forty) plants are selected for the production of succulent biomedicines at the primary or pilot effort. Plants with reports of use by the communities for decades as some foods, food additives, or medicines are given preference during keeping in this list with an expectation of nil or very low toxicity of these in their therapeutic doses.



Some adoptive research is required before the use of the succulent parts of these medicinal plants as well as any other plant with a report of anti-diabetic activities. Use of some biomedicines as some basic therapy, use of a few biomedicines together for a period and then use of another a few, etc. subjects are to be standardized with such research.

In the plant-wise description, along with details of the plant, some related research report/s are also added for each of them [table 2]

**Table 2** Selected plants for anti-diabetes succulent biomedicine preparation

Plant name with Family	Common Name	Medicinal part/s and proposed form of use	References
<i>Aegle marmelos</i> L. [Rutaceae]	Bengal quince	Leaf and callus (paste)	Antidiabetic, antioxidant [29,30]
<i>Allium sativum</i> L. [Amaryllidaceae]	Garlic	Bulb (paste)	Antidiabetic, antilipidemic [31] renoprotective, anti-atherosclerotic, antimicrobial, antihypertensive [32]
<i>Andrographis paniculata</i> (Burm. f.) Nees. [Acanthaceae]	Creast	Leaf (paste)	Antidiabetic, antihyperlipidemic [33,34]
<i>Annona squamosa</i> L. [Annonaceae]	Sugar apple	Young leaf (paste)	Antidiabetic [35], antioxidant, assist in lipid metabolism [36]
<i>Azadirachta indica</i> A. Juss. [Meliaceae]	Indian lilac	Leaf (Paste)	Antidiabetic [37], antiinflammatory, antipyretic, antimicrobial, antidiabetic etc. [38]
<i>Bauhinia purpurea</i> L. [Fabaceae]	Orchid tree	Leaf, flower, stem bark (paste/powder)	Antidiabetic [39,40]
<i>Beta vulgaris</i> L. [Amaranthaceae]	Beet	Root (paste/juice)	Antidiabetic, haematinic [41], prevent liver damage [42]
<i>Catharanthus roseus</i> (L.) G. Don. [Apocynaceae]	Graveyard plant	Leaf/ soft stem (paste)	Antidiabetic [43], hypolipidaemic [44]
<i>Cinnamomum verum</i> J. Presl. [Lauraceae]	True cinnamon	Stem bark (powder)	Antidiabetic [45], antioxidant and anticholinergic [46]
<i>Citrullus colocynthis</i> (L.) Schrad. [Cucurbitaceae]	Bitter apple	Fruit, leaf (paste)	Antidiabetic [47,48]
<i>Coccinia grandis</i> (L.) Voigt. [Cucurbitaceae]	Ivy gourd	Leaf, root (paste)	Antidiabetic [49], antihyperlipidemic, antioxidant [50]
<i>Costus igneus</i> N. E. Br. [Costaceae]	Insulin plant	Leaf (paste)	Antidiabetic [51,52]
<i>Curcuma longa</i> L. [Zingiberaceae]	Turmeric	Rhizome (paste)	Antidiabetic [53], hepatoprotective with antioxidant activity [54]

<i>Cyperus rotundus</i> L. [Cyperaceae]	Nutgrass	Rhizome (paste/powder)	Antidiabetic [55], antioxidant [56]
<i>Daucus carota</i> subsp. <i>sativus</i> var. <i>atrorubens</i> Alef. [Apiaceae]	Black carrot	Taproot (paste)	Antidiabetic, anticholesterol, antioxidant [57,58]
<i>Emblica officinalis</i> Gaertn. [Phyllanthaceae]	Indian gooseberry	Fruit (paste)	Antidiabetic, antioxidant [59,60]
<i>Embelia ribes</i> Burm. f. [Primulaceae]	False black pepper	Berries (paste/powder)	Antidiabetic [61], antioxidant [62]
<i>Foeniculum vulgare</i> Mill. [Apiaceae]	Fennel	Fruit (powder/paste)	Antidiabetic [63,64]
<i>Gymnema sylvestre</i> R. Br. [Apocynaceae]	Gymnema	Leaf (paste)	Antidiabetic [65,66]
<i>Hemidesmus indicus</i> (L.) R. Br. [Apocynaceae]	Indian sarsaparilla	Root (paste/powder)	Antidiabetic [64,67] anti-hypercholesterolemic [68]
<i>Hibiscus sabdariffa</i> L. [Malvaceae]	Roselle	Leaf, flower (paste)	Antidiabetic [69] antilipidemic [70]
<i>Lithocarpus polystachyus</i> Wall. ex A.DC. [Fabaceae]	Sweet tea	Leaf (paste/powder/decoction)	Antidiabetic [71] antioxidant, cardioprotective, hepatoprotective, anticancer [72]
<i>Momordica balsamina</i> L. [Cucurbitaceae]	Balsam apple	Fruit, leaf (paste)	Antidiabetic [73] Prevent kidney damage, and reduce high blood pressure [74]
<i>Moringa oleifera</i> Lam. [Moringaceae]	Drumstick tree	Leaf, flower, pod (paste)	Antidiabetic [75] antioxidant [76]
<i>Ocimum sanctum</i> L. [Lamiaceae]	Holy basil	Aerial part (paste)	Antidiabetic, antioxidant [77] anticholesterol, hepatoprotective [78]
<i>Picrorrhiza kurroa</i> Royle ex Benth. [Plantaginaceae]	Kutki	Rhizome (Succulent/dry) (paste/powder)	Antidiabetic [79,80]
<i>Piper cubeba</i> L.f. [Piperaceae]	Java pepper	Berry (powder/paste)	Antidiabetic, antioxidant [81] antimicrobial, hepatoprotective, nephroprotective, anti-cancerous [82]
<i>Piper longum</i> L. [Piperaceae]	Indian long pepper	Fruit (powder/paste)	Antidiabetic and antihyperlipidemic [83,84]
<i>Piper nigrum</i> L. [Piperaceae]	Peppercorn	Fruit (powder/paste)	Antidiabetic [85,86]
<i>Salvia hispanica</i> L. [Lamiaceae]	Chia	Seed (powder/paste)	Antidiabetic [87], antioxidant [88]
<i>Smilax aspera</i> L. [Smilacaceae]	Sarsaparille	Root (paste/powder)	Antidiabetic, antioxidant [89] Rheumatism [90]
<i>Swertia chirayita</i> (Roxb.) H.Karst.	Chirayata	Leaf (paste)	Antidiabetic [91,92]

[Gentianaceae]			
<i>Syzygium cumini</i> (L.) Skeels. [Myrtaceae]	Black plum	Bark, Fruit, Seed (paste/powder)	Antidiabetic [93,94]
<i>Terminalia chebula</i> Retz. [Combretaceae]	Chebolic myrobalan	Fruit pulp (dry) (powder)	Antidiabetes, anti-hyperlipidaemic renoprotective [96] [95]
<i>Trigonella foenum-graecum</i> L. [Fabaceae]	Fenugreek	Leaf and Seed (paste/powder)	Antidiabetes [97], anti-hyperlipidaemic [98]
<i>Tinospora cordifolia</i> (Thunb.) Miers. [Menispermaceae]	Giloy	Stem (paste)	Antidiabetic [99], immunomodulatory, antioxidant, hepatoprotective [100]
<i>Vaccinium arctostaphylos</i> L. [Ericaceae]	Caucasian whortleberry	Fruit (paste/powder)	Antidiabetic [101,102]
<i>Vernonia amygdalina</i> Delile. [Asteraceae]	Bitter leaf	Leaf (paste)	Antidiabetic [103], protects pancreas, liver, and spleen [104]
<i>Zingiber officinale</i> Roscoe. [Zingiberaceae]	Ginger	Rhizome (paste)	Antidiabetic [105,106]
<i>Zingiber zerumbet</i> (L.) Roscoe ex Sm. [Zingiberaceae]	Bitter ginger	Rhizome (paste)	Antidiabetic [107,108]

### 3.3 Preparation of anti-diabetic succulent biomedicines

#### 3.3.1 Collection of materials

Medicinal plants may be cultivated in the area of their natural soil and climate, preferably without using synthetic pesticides and fertilizers. The production centers of the biomedicines may be near their cultivation area.

#### 3.3.2 Collection of cut pieces, pastes, juices from succulent plant parts, and powders from the dry seeds

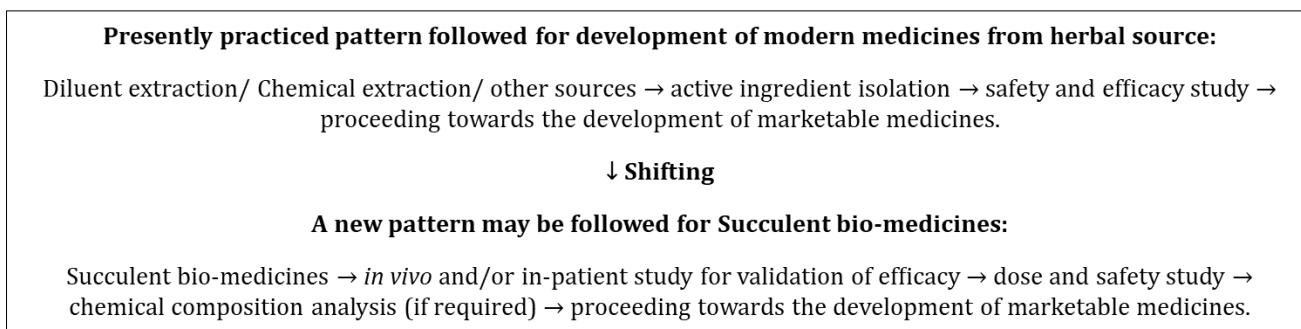
The succulent parts of the medicinal plants may be collected in a sterile condition before processing. As per the requirement, the cut pieces, paste, juice, etc. should be collected from these plant parts. The dry seeds are to be converted to powder. All such procedures are to be performed in a sterile environment.

#### 3.3.3 Validation of activities, a study of toxicity, determination of indication, doses, etc.

Some indications regarding the form of the medicines for their oral use are stated in the list, but these also require validation through thorough adaptive research. Likewise, for the establishment of standard doses depending on the severity of diseases and other parameters related to the patients, further study is required.

Like the medicines of synthetic origin (Modern medicine), efficacy and toxicity studies of these medicines are also required. But such a study may be performed only on the succulent form of the medicines, not on any extracts or in the dry form. The available techniques are to be modified to perform the work effectively.

The change in the study concept may be in the line with the pattern shown in figure 1.



**Figure 1** Conceptual shifting of study for validation of medicines for development of succulent biomedicines [19]

### 3.3.4 Standardization of indications and doses

For calculation of doses and indications of use of the anti-diabetic biomedicines, the *in vivo* study/animal study and then study on volunteers or the patients may be given preference.

During production, the individual dosing of the succulent biomedicines may be calculated batch-wise at the production centers depending upon the concentration of the available major phytochemicals in the plant parts and matching of them with the predesigned standard chart, as the availability of phytoconstituents may not be constant in the raw materials obtained from different sources and at different seasons of the year. It may be variable with the factors like the breed of the plants, the type of soil, stage of growth of the plant during material collection, climate during cultivation of the plant, and many other related factors. For correction of possible variation in the concentration of the phytochemicals, mixing of raw materials collected from different sources may be considered. Correction of soil constituents or other related parameters may also be performed as per the research recommendations.

### 3.3.5 Preservation and encapsulation of the succulent biomedicines

The succulent biomedicines for the control and cure of diabetes may be encapsulated after the addition of bio-preservatives if required. Several bio-preservatives are available, but these are to be studied for addition with individual biomedicines. Essential oils of the plants like Basil, Clove, Coriander, Onion, Cinnamon, Ginger oil, Lemon, Mount Atlas mastic, Garlic, Rosemary, Mint Thyme, Oregano, Thyme, Allspice, Bergamot, Mustard, Nutmeg, Sage, Vanilla, Eucalyptus, *Artemisia anomala*, *Zizyphus jujuba*, *Callistemon lanceolatus*, etc. may be tested for use as some bio-preservative [109,110].

There are many other herbs, spices, natural substances, insect, animal, and bird origin products, etc. that can also be used after proper study [17].

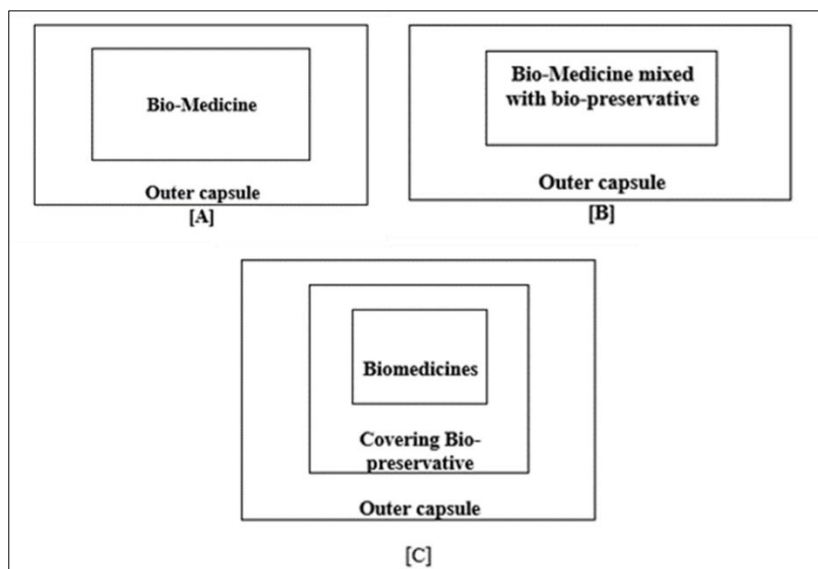
But, the previously collected essential oil or the concentrated juice of the original biomedicine may be the best bio-preservative, if found suitable [20].

For encapsulation, encapsulating materials from the biological origins may be given preference, if they suit the purpose. Plant materials like plant extracts (Soluble soybean, Pectin, Galactomannans, Cocoa butter), plant exudates (Gum Arabic, Mesquite gum, Gum karaya); Polysaccharides, Starch, and Cellulose derivatives; proteins like Gluten (corn), isolates of Pea or Soy, Wheat gluten; lipids like Glycerides, Fatty acids or alcohols, Waxes (Bee wax, Carnauba wax, Candelilla wax), Phospholipids, Shellac resin, etc. can be tested as an agent of bio-encapsulation.

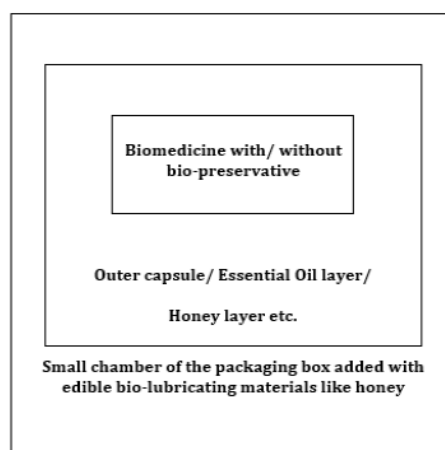
Marine products like Alginate or Carrageenan; microbial or animal products like Gelatin, Chitosan, Collagen, Xanthan, Dextran, Gellan, Caseins, Corn, Whey proteins, etc. may also be tested [109,110].

As some instant option in the initial study, only collagen or a combination of collagen and some cellulose item or any soft gel capsular materials may be tested for their efficacy.

The biomedicines may be directly encapsulated, or maybe mixed and/ or coated with bio preservatives before encapsulation. Some techniques are identified which may be followed with modifications as per the requirement of the individual biomedicine [figure 2]. Special packaging techniques may be required for the packaging of these biomedicines. One sample packaging technique is shown in figure 3.



**Figure 2** Sample processes of succulent biomedicine encapsulation [A) Bio-Medicine covered by bio-capsule; B) Bio-medicine mixed with bio-preservative and covered by bio-capsule; C) Bio-medicine coated with bio-preservative and covered by bio-capsule][20]



**Figure 3** A sample packaging technique for succulent biomedicines [20]

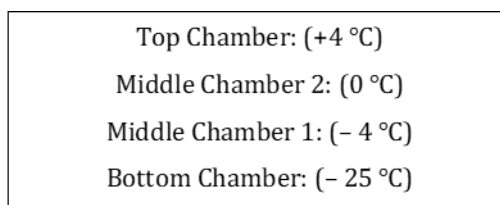
### 3.3.6 Addition of spoilage indicator

Among the different spoilage indicators, the use of different Vaccine Vial Monitor (VVM) chemicals may be the most acceptable option as some spoilage indicators on the packets of the succulent biomedicines [20]. As the biomedicines are to be transported under a cold chain, the selection of specific temperature-sensitive VVM chemicals for specific biomedicine is important.

### 3.3.7 Freezing and transportation of the biomedicines up to the patients or consumers

The main backbone of the storage and transportation of these biomedicines is the rigid maintenance of the cold chain from the production center up to the patients or consumers.

For long time storage of such materials, the temperature may be better below - 23°C [111]. So, as some routine practice, it may be - 25°C, until reports for individual biomedicines are available [20]. For storage at the retailer store, some specially designed refrigeration systems may be adopted with four different chambers having storage temperatures of (- 25°C, - 4°C, and 0°C and in special cases, + 4°C from the bottom [figure 4].

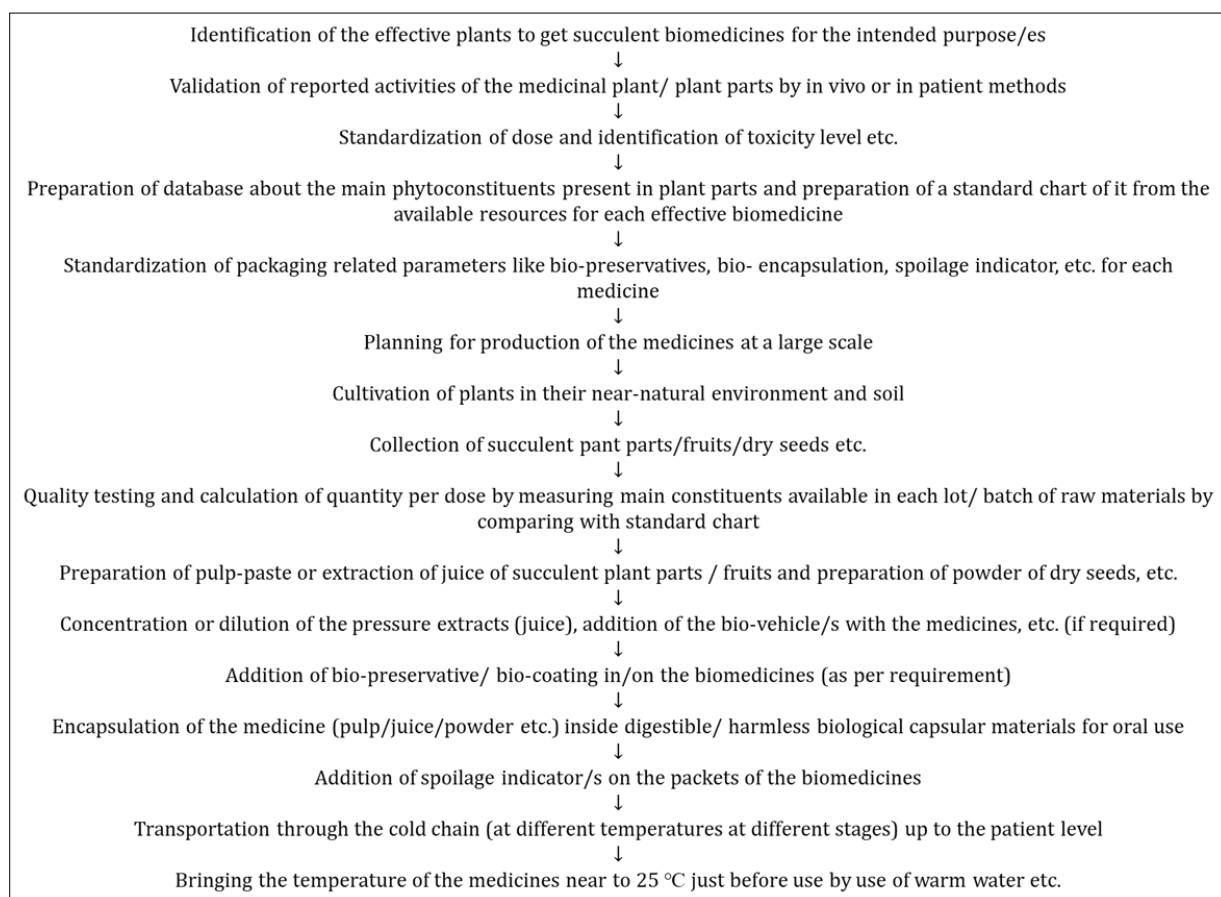


**Figure 4** A sample design of storage arrangement of succulent biomedicines (design of freezing chambers with different temperatures to stock succulent biomedicines) [20]

The consumers may be advised to take the biomedicines after bringing the temperature near to 25°C (or at room temperature). Warm water may be used for that purpose. But a thorough study is required for standardization of each step to prepare the final indications of use for individual biomedicine.

As most medicinal plants generally grow at some particular season/s, so there should be ample facilities for storage of the collected raw materials or the encapsulated medicines near the production centers for continuous global supply throughout the year.

Different aspects of the production of succulent biomedicines are shown briefly in figure 5.



**Figure 5** Production and transport of proposed succulent biomedicines [19]

### 3.3.8 Requirement of legislative control on the entire procedure

The use of succulent biomedicines for the control and cure of different diseases is a new concept. So, the related existing rules may not be effective enough to control all possible malpractices and misuses during the production and use of these medicines. Furthermore, there are ample scopes for adulteration and sabotage in the different steps of the proposed system - from the collection of materials, preparation of biomedicines from them, storage, transportation, and

up to their use [20]. So, one separate legislative control applicable to the succulent biomedicines is required which has to cover the biomedicines of diabetes.

### 3.4 Lifestyle factors related to the prevention of diabetes.

Besides genetic predisposition, non-burning out of taken calories and disbalance in normal physiological mechanisms for utilization of such calories are the main factors working behind the initiation and progression of type 2 diabetes. Along with these well-known lifestyle-related factors, many other factors are there that are not less important. These may not be felt like some important factors from the eye of modern medicine, but their activities are noticed by many researchers. Staying away from the intake of toxins through food and drinks by excluding processed foods and chemical added drinks, tobacco, alcohol, etc. from the diet schedule, regular exposure to green nature during morning and evening walks for at least 40 - 60 minutes, exposure to morning sun for 15-20 minutes, practicing yoga, etc. are some such factors.

The validation study of reported activities of the anti-diabetic plants is traditionally performed only on the solvent extracts of dry parts of the medicinal plants. Methyl alcohol, ethyl alcohol, acetone, etc. diluents are used to get the solvent extracted portions from them, and then efforts are made to identify active principles from such extracts to prepare synthetic drugs. But these contemporary efforts fail to supply any marketable anti-diabetic drug with satisfactory effects still date. Questions have been raised on the actual effectiveness of that contemporary procedure of validation of reported activities only through the diluent extracted sections of the dry parts of the medicinal plants, as these do not represent the cumulative effects of all the phytoconstituents available in the medicinal plant parts. Furthermore, the dry medicinal plant parts themselves are lacking in many phytoconstituents of the original plant, as many of them are lost during the drying process. So, the contemporary procedure cannot be considered as a complete study of validation of activities of any medicinal plant part [15]. As no study report is found on the evaluation of the anti-diabetic activity of the medicinal plant parts at their succulent or naturally available state, the available reports of contemporary studies are used as the references in this article.

Unlike modern medicines, almost every succulent biomedicine has multi-dimensional beneficial effects on health. The non-communicable diseases (NCD) cause a huge number of deaths in different countries, and in India, it is almost 61% of all deaths [112]. Along with diabetes, cardiovascular diseases, cancers, different respiratory diseases, etc. fall under this category. Along with preventive and/or curative effects of single or a few diseases together, many such biomedicines can also act to prevent different NCDs and also provide many important micronutrients to the body. For example, leaf and flower *Hibiscus sabdariffa* L. can prevent or cure diabetes, reduce cholesterol levels, can reduce blood pressure, etc. along with the supply of many important macro and micronutrients [113].

The mechanism of action of the succulent biomedicines may be diverse. As every single succulent biomedicine contains a huge number of active phytoconstituents, the ultimate physical expression of any of this biomedicine possibly follows more than one mechanism [20,114,115]. Prevention or slowing down of absorption of glucose from the gut, increase in conversion of glucose to glycogen, increase of secretion of insulin from the pancreas by acting on beta cells, modification of activities of the insulin receptors of the tissues, increase utilization of glucose by the tissues following any known or still unknown pathways, etc. maybe some of the possible mechanisms. The concept of the cumulative effect of a huge number of available phytoconstituents and their interactions, different anti-oxidation activities of succulent biomedicines, immunomodulation activities of different manners, activities as some preventive agent for many other diseases, supply of important micronutrients, and many other unknown or partially known related mechanisms may work together [20]. The activities of anti-diabetic succulent biomedicines have to be analyzed under that light.

So, identification of the actual total anti-diabetic mechanism of the effective succulent biomedicines is more important than such study on individual active principle/s, and so the subject requires intense study with a separate analytical system.

Some anti-diabetic biomedicines may act mainly as some preventive medicine among the pre-diabetic persons, some others may act mainly as some curative agent among the diabetic patients and some may act for both. For example, the principal effects of plants like *Tinospora cordifolia* (Thunb.) Miers, *Allium sativum* L., *Hibiscus sabdariffa* L., etc. may be preventive, and activities of *Costus igneus* N.E.Br., *Catharanthus roseus* (L.) G. Don. etc. may be mainly curative. Use of more than one succulent biomedicine may also be considered as per their requirement in the individual patient.

There are several reports of intake of high-energy foods is directly related to an increase in blood glucose levels and more burning of calories can act as the reverse. So, a proper diet and regular physical exercise can prevent or reduce the severity of diabetes.

Among the dietary factors, diets rich in green, leafy vegetables, different pulses, salads, nuts, probiotic food (like yogurt), and less easily accessible carbohydrate is beneficial to controlling diabetes [19,119]. Diets chiefly having such vegetable items are also capable of supplying different antioxidants along with a good amount of fiber and other phytochemicals to the body [19], all of which are beneficial to control diabetes. Vegan diets contain many such items and they can control blood sugar and cholesterol levels [117]. But common criticism of the vegan diet is that it cannot supply some very important vitamins and minerals; like vitamin B12, riboflavin, vitamin D, minerals like calcium, iron, iodine, zinc, etc. [117]. The milk, meat, fish, egg, and their products can supply vitamin B12 directly. But a wise selection of vegan items can remove all such problems. For the strict followers of vegan diets, dried purple laver (*Porphyra* sp.; nori - edible seaweed), different fermented beans and vegetables, edible algae, edible mushrooms, etc. can supply vitamin B12 [118]. Apart from different fruits, succulent parts of some plants can supply many other debated nutrients to us. For example, only *Hibiscus sabdariffa* L. can supply calcium, magnesium, vitamin A, vitamin C, potassium, iron, magnesium, manganese, etc. along with carbohydrate, fat, and protein [113].

But for the persons not accustomed to such vegan diet items, sudden conversion of their diet to the vegan items cannot be continued easily for a long time. They will feel the urge to return to their previous diet [117]. In such a condition, intake of capsules of succulent biomedicines may be the right option.

So, intake of high-calorie foods and easily available sugar-containing foods or drinks, intake of different processed foods, etc. added with less physical activities, low supply of different antioxidants and immuno-modulates through diet, staying away from the nature, supplying of different synthetic and toxic chemicals through food and drinks to the body which acts together with different xenobiotic residues cumulatively, etc. factors working behind the disbalance of the controlling system of the body and act as some triggering agents for t2d [17,19,116].

As per the research reports, the presence of a good level of vitamin D in the blood [120] and avoidance of stress and other related psychosocial variables can also act to prevent the initiation and magnitude of diabetes [121,122].

Exposure to sunlight to produce vitamin D naturally inside the body and passing time with nature to reduce mental stress may be some effective options. The effect of regular exposure to sunlight for a brief period is having many beneficial health effects, including a reduction in the chance of developing diabetes. It is said that sunlight exposure can cause the production of vitamin D in our skin which can cause such health impacts. But only supplementation of vitamin D as some medications cannot show the same effects as the sunlight exposure. This difference between the observational study reports and the result of interventional studies perhaps proves the actual effect of nature on our health, many parts of which are perhaps still not known to us [123].

The practice of Yoga and alike procedures can also assist in relaxation from mental stress [123,124]. Morning and/or afternoon walking at the park or any space with green plants and trees can assist in the prevention or delay development as well as reduction of severity of many diseases including diabetes. There is scientific evidence of reduction of risk of development of diabetes as well as reduction of risk of development of obesity in the section of common people visit green spaces regularly [124].

The succulent biomedicines will act in a far better way in a favorable environment inside our body system. So, identification of lifestyle-related lacunae individually and their correction is needed for getting the highest level of activities of these biomedicines.

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#### 4. Conclusion

Fire cannot start burning without fuel, and even start burning, fail to continue if the supply of fuel is disconnected. Reduction of availability of glucose at high concentration at a time by eating a high fiber low-calorie diet, abstaining from all kinds of processed foods and drinks, abstaining from intake of the synthetic chemicals of different names, etc., provision of supply of different secondary metabolites, antioxidants, etc. through unprocessed foods, succulent seasonal fruits, etc. to the body, regular exposure to the green nature and the morning sunlight, provision of ample physical exercise, staying away from the pressure situations or at least getting gaps in it, etc. can even prepare the base to mask the ultimate physical expression of even the genetic predisposition of type 2 diabetes. Along with such practices, the intake of succulent biomedicines as a preventive or curative agent for diabetes may be the preferable option to combat the disease.



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## Compliance with ethical standards

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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