Promising Plant Sources of Anti-Diabetic Micronutrients

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Abstract

Specialized foods (SF) with a predetermined chemical composition play an important role in the prevention of the most common nutrition-related diseases, including type 2 diabetes. Prospective sources of phytonutrients for SF include an analysis of the frequency of occurrence of edible and medicinal plants as part of multicomponent antidiabetic formulations traditionally used to treat DM in Russia, Belarus and Ukraine. To realize this goal, more than 200 publications have been analyzed. Of these, only 66 bibliographic sources contained multicomponent antidiabetic prescriptions in the form of collections from dried medicinal plant raw materials and multicomponent juices from fresh medicinal and edible plants. In total, in the identified 66 publications, we found 550 multi-component formulations. It is shown that the leader plants are Bilberry - Vaccinium myrtillus L., Common beans-Phaseolus nanus L., Phaseolus vulgaris (L.) Savi var. nana Ach. and Great nettle-Urtica Dioica L. The results of this study can serve as the basis for the development of SF with a predetermined chemical composition using edible and medicinal plants.

Keywords: Food ingredients; Type 2 diabetes mellitus; Specialized food products; Traditional anti-diabetic recipes; Medicinal plants; Bilberry; Common bean; Great nettle

Introduction

Modern foods should not only satisfy the organism's physiological demand for nutrient materials and calories, but also serve preventive and therapeutic purposes of recovery and normalization of metabolic processes in the organism [1,2]. Phytonutrients (micronutrients produced by plants) are considered as important components of the organism's nutriome which ensure optimal performance of all its systems at the required level of its adaptive potential [3,4]. Natural sources of such phytonutrients include traditional edible and medicinal plants [3,5] which contain biologically active substances that have apparent physiological (sometimes specific) effect upon the organism [2,5-9].

Specialized foods (SF) with a predetermined chemical composition play the most important role in the preventive treatment of the most common nutrition-related diseases and are predominately used in the nutrition of patients [1,2,5]. The urgent task for food industry specialists, pharmacognosists and nutritionists is to find promising sources of phytonutrients for development of special foods (with significant biological activity and good application properties) for patients with type 2 diabetes mellitus (DM).

The objective of this informational and analytical study is to discover promising plant sources of phytonutrients for development of anti-diabetic special foods with the use of ethno botanical and ethno medical approaches.

Materials and Methods

In the course of the study, the following methods were applied: informational and analytical study, historical study, content analysis and categorization, grouping, rating, comparative and structural analyzes.

The methods applied in the search for promising sources of phytonutrients for special foods included an analysis of ethno botanical and ethno medical literature for frequency of mention of edible and medicinal plants used as components of multi-component anti-diabetic formulations traditionally applied for diabetes mellitus treatment in Russia and neighboring European countries (Belarus and Ukraine) followed by identification of the plants that are used most often.

We proceeded from the assumption that the index of frequency of mention in conventional formulation reference books in per cent of the total number of the analyzed publications can serve as an indirect proof of both the popularity in indigenous (traditional) medicine and the effectiveness of a specific plant for prevention and treatment of diabetes mellitus. In our experience, such an assumption can be considered accurate provided that an informational and analytical study is performed on at least 50 formulation references comprising at least 500 traditional formulations [5,10].

The study was performed on available literature published between 1959 and 2014 in Russia, Belarus, and Ukraine, including reference books, monographs, and collections of traditional and indigenous medicine formulas. The total number of the analyzed publications on the study subject exceeded 200. From those, only 66 publications contained multicomponent anti-diabetic formulations in the form of species made of dried medicinal plants and multi-component saps made of fresh medicinal and edible plants. In the selected 66 formulation reference books [6,11-75], we have identified 550 multi-component formulations.
We have previously published the results of an analysis of the frequency of mention of plants of hypoglycaemic action in traditional and indigenous medicine formulation reference books [76]. It was determined that the most common plants were bilberry - *Vaccinium Myrtillus* L. (bilberry leaves are mentioned in 86.4%, and shoots are mentioned in 19.7% of the references), common bean - *Phaseolus Nanus* L., *Phaseolus Vulgaris* L. Savi var. nana Ach. (bean siliques are mentioned in 72.7%, and dried siliques are mentioned in 27.3% of the references), and great nettle - *Urtica Dioica* L. (leaves are mentioned in 74.2%, and grass is mentioned in 12.1% of the references).

This informational study is aimed at the analysis of the frequency of mention of medicinal and edible plants in traditional anti-diabetic formulations. The number of ingredients contained in multi-component formulations was calculated to be within the range from 2 to 12 (single-component formulations were excluded from the study). In total in the 550 anti-diabetic formulations studied (from all 66 publications analyzed), we have identified 230 names of edible and medicinal plant substances from 154 plants (from some plants, several morphological components were used, such as flowers, grass, leaves, roots). Closely related species of plants were considered as one plant, provided that the quality of the substance produced from them is currently regulated under the same reference document (a Pharmacopoeia Article, a State Standard).

Only 5 medicinal plant species, Bilberry (78.9%), Common Bean (34.7%), Galega Officinalis (31.8%), Great Nettle (31.6%), Common Dandelion (28.6%), were identified as the most commonly used (in more than 20% of the analyzed anti-diabetic formulations in Russia, Belarus and Ukraine). *Rosa canina* (various botanical species) was rated the sixth with the frequency of mention of 19.1%. The analysis of the frequency of mention of specific morphological components in the formulations revealed that more than 20% of the formulations include only 4 positions: bilberry leaves (75.3%), galega grass (31.5%), nettle leaves (26.2%) and bean coats (25.1%).

A summary rating of the frequency of mention of edible and medicinal plants in 66 formulation reference books of Russia, Belarus, Ukraine (in anti-diabetic formulations) [76] and in 550 traditional anti-diabetic formulations is provided in Table 1.

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Plant name</th>
<th>Rating of frequency of mention in 66 formulation reference books</th>
<th>Rating of frequency of mention in 550 formulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bilberry - <em>Vaccinium myrtillus</em>, L., Family Vacciniaceae</td>
<td>1</td>
<td>1</td>
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<tr>
<td>2</td>
<td>Common bean - <em>Phaseolus nanus</em> L., <em>Phaseolus vulgaris</em> (L.) Savi var. nana Ach., Family Fabaceae</td>
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<td>2</td>
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<td>3</td>
<td>Great nettle - <em>Urtica dioica</em> L., Family Urticaceae</td>
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<td>4</td>
<td>Common dandelion - <em>Taraxacum officinale</em> Wigg.s.l., Family Asteraceae</td>
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<td>5</td>
<td><em>Rosa</em> (various species) - <em>Rosa majalis</em> Herm. - (<em>Rosa cinnamomea</em>) L., Family Rosaceae</td>
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<td>6</td>
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<td>6</td>
<td>Wild strawberry - <em>Fragaria vesca</em> L., Family Rosaceae</td>
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<td>7</td>
<td>Greater burdock - <em>Arctium lappa</em> L., Family Asteraceae</td>
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<td>10</td>
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<td>8</td>
<td>Peppermint - <em>Mentha piperita</em> L., Family Lamiaceae</td>
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<td>7</td>
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<tr>
<td>9</td>
<td>Common chicory, wild - wild chicory (in many cases, its was specifically indicated that the plant was wild-growing) - <em>Cichonum intubus</em> L., Family Asteraceae</td>
<td>9</td>
<td>12</td>
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<tr>
<td>10</td>
<td>Perforate St John’s-wort (common Saint John’s wort) - <em>Hypericum perforatum</em> L., imperforate St John’s-wort (spotted St. John’s-wort) - <em>Hypericum maculatum</em> Grantz (H. quadrangulum) L. (various species), Family Hypericaceae</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>11</td>
<td>Field horsetail - <em>Equisetum arvense</em> L., Family Equisetaceae</td>
<td>10</td>
<td>11</td>
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<tr>
<td>12</td>
<td>Common oat - <em>Avena sativa</em> L., Family Poaceae (Gramineae)</td>
<td>10</td>
<td>15</td>
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<tr>
<td>13</td>
<td>Galega (goat’s-rue) - <em>Galega officinalis</em> L., Family Fabaceae</td>
<td>11</td>
<td>3</td>
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<tr>
<td>14</td>
<td>Lingonberry - <em>Vaccinium vitis ideae</em> L. Family Vacciniaceae</td>
<td>12</td>
<td>9</td>
</tr>
<tr>
<td>15</td>
<td>Common knotgrass, lowgrass - <em>Polygonum aviculare</em> L. Family Polygonaceae</td>
<td>12</td>
<td>9</td>
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<td>16</td>
<td>Common flax - <em>Linum usitatissimum</em> L., Family Linaceae</td>
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<td>14</td>
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<tr>
<td>17</td>
<td>Silver birch - <em>Betula pendula</em> Roth. (= B. alba L.), Family Betulaceae</td>
<td>14</td>
<td>17</td>
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</table>
As is evidenced by Table 1, the absolute leaders of the rating are: bilberry (leaves, shoots), bean (silique valves), and great nettle (leaves, grass). All three plants are sources of commonly used and high production volume medicinal herbal substances in Russia, and are therefore promising for further pharmacological and production studies. Considering the significant number of contraindications to the application of galega officinalis grass and seeds [11,77-81], as well as its placement at the 11th position in the ranking of formulation reference books [76], it hardly seems feasible to include components of this alkaloid-bearing plant into the list of promising plant sources of essential nutrients for anti-diabetic special foods.

Starting from position 33 (Table 1) the grading of plants has no sense, because the mention frequency in reference books can differ from mention frequency in formulations (Table 1, lines 33-37). From our point of view, this can be explained by large territory of Russia, covering several climatic zones, and also by the wish of people to be treated with local plants. For example, devil`s-club (Table 1, line 33) grows in the Far-East region of Russia, 9000 km from western borders of Russian Federation. This limits significantly the frequency of including the roots of this plant into anti-diabetic formulations of western regions of Russia, and also Ukraine and Belarus (Table 1, line 33, column 4, position 76). In the same time, Calendula officinalis L. (Table 1, line 37, column 4, position 26) is one of the most favorite medicinal and decorative plants in Russia, cultivated in almost all climatic zones except Far North. For pot marigold flowers (Flores Calendulae) we didn’t find any verified data (experimental or clinical}

Table 1: Edible and medicinal plants most commonly used in traditional anti-diabetic formulations in Russia, Belarus, Ukraine (in the descending order).

<table>
<thead>
<tr>
<th>No.</th>
<th>Common Name (Genus, Species)</th>
<th>Family</th>
<th>Rank in Formulations</th>
<th>Rank in Reference Books</th>
</tr>
</thead>
<tbody>
<tr>
<td>18</td>
<td>Black elder - Sambucus nigra L., Family Caprifoliaceae</td>
<td>15</td>
<td>15</td>
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<td>19</td>
<td>Morus (no species specified), mulberry - Morus alba L., Family Moraceae</td>
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<td>13</td>
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<tr>
<td>20</td>
<td>Elecampane - Inula helenium L., Family Asteraceae</td>
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<td>21</td>
<td>Large plantain - Plantago major L., plantain lanceolate - Plantago lanceolate L. Family Plantaginaceae</td>
<td>16</td>
<td>21</td>
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<tr>
<td>22</td>
<td>Pharmaceutical camomile - Matricaria recutita (L.) Rauschert (= M. chamomilla L. = Chamomilla recutita (L.) Rausch.) Family Asteraceae</td>
<td>17</td>
<td>18</td>
<td></td>
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<tr>
<td>23</td>
<td>Motherwort - Leonurus cardiaca L. Motherwort five-bladed, hairy - Leonurus quinquilobatus Gilib. (= L. villosus Desf.) Family Lamiaceae</td>
<td>18</td>
<td>21</td>
<td></td>
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<td>24</td>
<td>Walnut - Jugans regia L. Family Juglandaceae</td>
<td>19</td>
<td>19</td>
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<td>25</td>
<td>Yarrow - Achillea millefollium L. Family Asteraceae</td>
<td>20</td>
<td>27</td>
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<td>26</td>
<td>Bur beggar-ticks - Bidens tripartita L. Family Asteraceae</td>
<td>21</td>
<td>26</td>
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<tr>
<td>27</td>
<td>Blackcurrant - Ribes nigricum L. Family Saxifragaceae</td>
<td>21</td>
<td>22</td>
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</tr>
<tr>
<td>29</td>
<td>Flint corn - Zea mays L. Family Poaceae (Gramineae)</td>
<td>22</td>
<td>20</td>
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<tr>
<td>30</td>
<td>Heliotrope - Valeriana officinalis L. Family Valerianaceae</td>
<td>23</td>
<td>23</td>
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<tr>
<td>31</td>
<td>Yellow everlasting - Helichrysum arenarium (L.) Moench. (= Gnaphalium arenarium L.) Family Asteraceae</td>
<td>24</td>
<td>24</td>
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<tr>
<td>32</td>
<td>Maybush - Crataegus laevigata (Poir) DC. Redhaw hawthorn-Crataegus sanguinea Pall. Family Rosaceae</td>
<td>24</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Devil's-club - Echinopanax elatum Nakai (syn. Oplopanax elatum Nakai) Family Araliaceae</td>
<td>24</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>European centaury-Centaurium erythraea Rafn.(C. minus Moench. = C. umbellatum Gilib. = C. pulchellum (Sw.) Druce) Family Gentianaceae</td>
<td>24</td>
<td>24</td>
<td></td>
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<tr>
<td>35</td>
<td>Mouse-ear - Gnaphalium uliginosum L.s.l. Family Asteraceae</td>
<td>24</td>
<td>26</td>
<td></td>
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<tr>
<td>36</td>
<td>European dewberry-Rubus caesius L. Family Rosaceae</td>
<td>42</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Pot marigold - Calendula officinalis L. Family Asteraceae</td>
<td>61</td>
<td>26</td>
<td></td>
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</tbody>
</table>
studies) on their hypoglycemic activity. In the same time pot marigold flowers contain carotenoids and large polyphenol complex, have anti-inflammatory and regenerative activity and are included in State Register of Medicinal Remedies Approved in Russian Federation, and also are very popular among the people.

Besides the plants, most frequently used in reference books and antidiabetic formulations, stated in Table 1, other edible and medicinal plants, used in traditional antidiabetic formulations of Russia, Belarus and Ukraine, are presented in the following list alphabetically:

- Ache- *Apium graveolens* L. (Apiaceae),
- Aerva woolly- *Aerva lanata* (L.) Juss. ex Schult. (Amaranthaceae),
- Alder- *Alnus incana* (L.) Moench (Betulaceae),
- American artichoke- *Helianthus tuberosus* L. (Asteraceae),
- Anise- *Anisum vulgare* Gaertn. (Apiaceae),
- Annual nettle- *Urtica urens* L. (Urticaceae),
- Aspen- *Populus tremula* L. (Salicaceae),
- Bachelor’s-button- *Centaura cyanus* L. (Asteraceae),
- Baical skullcap- *Scutellaria baicalensis* Georgi (Lamiaceae),
- Barren myrtle- *Arctostaphylos uva-ursi* (L.) Spreng. (Ericaceae),
- Bean trefoil- *Menyanthes trifoliata* L. (Menyanthaceae),
- Bay laurel- *Laurus nobilis* L. (Lauraceae),
- Beet sugar- *Beta vulgaris* L. (Chenopodiaceae),
- Bog whortleberry- *Vaccinium uliginosum* L. (Ericaceae),
- Bedstraw- (Rubieae) (Gentianales),
- Beet sugar- *Beta vulgaris* L. (Chenopodiaceae),
- Berbine- *Veronica officinalis* (Verbenaceae),
- Blindweed- *Capsella bursa-pastoris* (L.) medik. (Brassicaceae),
- Bog whortleberry- *Vaccinium uliginosum* L. (Ericaceae),
- Broad-leaved clover- *Trifolium pratense* L. (Fabaceae),
- Brussels sprouts- *Brassica oleracea* var. gemmifera (Brassicaceae),
- Burdock- *Xanthium strumarium* L. (Asteraceae),
- Burnet saxifrage- *Pimpinella saxifraga* L. (Apiaceae),
- Calamus root- *Acorus calamus* L. (Araceae),
- Cauliflower- *Brassica oleracea* var. gemmifera (Brassicaceae),
- Cucumber- *Cucumis sativus* L. (Cucurbitaceae),
- Cultivated angelica- *Arctium lappa* L. (Apiaceae),
- Cultivated apple- *Malus domestica* Borkh. (Rosaceae),
- Cultivated cabbage- *Brassica oleracea* L. (Brassicaceae),
- Danewort- *Sambucus ebulus* L. (Adoxaceae, Caprifoliaceae),
- Dense Mistletoe- *Viscum album* L. (Loranthaceae),
- Devil’s apron- *Laminaria saccharina* (L.) J.V.Lamour. (Phaeophyceae, Laminariaeaceae),
- Dock- *Rumex acetosa* L. (Polygonaceae),
- English primrose- *Primula veris* L. (Primulaceae),
- European ash- *Fraxinus excelsior* L. (Oleaceae),
- European dogwood- *Viburnum opulus* L. (Caprifoliaceae),
- FenNEL- *Foeniculum vulgare* Mill. (Apiaceae),
- Fenugreek- *Trigonella foenugracea* L. (Fabaceae),
- Field-ash- *Sorbus aucuparia* L. (Rosaceae),
- Field violet- *Viola arvensis* Murray (Violaceae),
- French spin- *Atriplex hortensis* L. typ. cons. (Amaranthaceae),
- French willow- *Chamerion angustifolium* L. (Onagraceae),
- Garden carrot- *Daucus carota* (Hoffm.) Roehl. (Apiaceae),
- Garden sage- *Salvia officinalis* L. (Lamiaceae),
- Garlic- *Allium sativum* L. (Liliaceae),
- Grape- *Vitis vinifera* L. (Vitaceae),
- Greater celandine- *Chelidonium majus* L. (Papaveraceae),
- Greek valerian polemonium- *Polemonium caeruleum* L. (Polemoniaceae),
- Heartsease- *Polemonium caeruleum* L. (Polemoniaceae),
- Heartsease- *Viola tricolor* L. (Violaceae),
- Hemp eupatorium- *Eupatorium cannabinum* L. (Asteraceae),
- Herb bennet- *Geum urbanum* L. (Rosaceae),
- Herb of grace- *Ruta graveolens* L. (Rutaceae),
- Herb of grace- *Ruta graveolens* L. (Rutaceae),
- Herbs for grace- *Ruta graveolens* L. (Rutaceae),
- Iceland moss- *Cetraria islandica* (L.) Ach. (Parmeliaceae),
- Indian kidney tea- *Orthosiphon stamineus* Benth. (Lamiaceae),
- Indian kidney tea- *Orthosiphon stamineus* Benth. (Lamiaceae),
- Indian kidney tea- *Orthosiphon stamineus* Benth. (Lamiaceae),
- Indian kidney tea- *Orthosiphon stamineus* Benth. (Lamiaceae),
- Indian kidney tea- *Orthosiphon stamineus* Benth. (Lamiaceae),
- Indian kidney tea- *Orthosiphon stamineus* Benth. (Lamiaceae),
- Indian kidney tea- *Orthosiphon stamineus* Benth. (Lamiaceae),
- Kollomikta-vine- *Actinidia kolomikta* Maxim. & Ruhr. (Actinidiaceae),
- King’s clover- *Meliolus officinalis* L. Pall. (Fabaceae),
- Lady’s mantle- *Alchemilla vulgaris* L. (Ranunculaceae),
- Lady’s mantle- *Alchemilla vulgaris* L. (Ranunculaceae),
- Leather berberina- *Berberis aristata* (L.) Fritsch (synonyms: B. cordifolia (Haw.) Sternrb., B. aristata var. cordifolia (Haw.) Boriss, Saxifraga cordifolia Haw.) (Saxifragaceae),
- Leather berberina- *Berberis aristata* (L.) Fritsch (synonyms: B. cordifolia (Haw.) Sternrb., B. aristata var. cordifolia (Haw.) Boriss, Saxifraga cordifolia Haw.) (Saxifragaceae),
- Lettuce- *Lactuca sativa* L. (Asteraceae),
- Lemon- *Citrus limon* L. (Osbeck) (Rutaceae),
- Lemon- *Citrus limon* L. (Osbeck) (Rutaceae),
- Lime- *Citrus aurantifolia* (Thunb.) Osbeck (Rutaceae),
- Mistletoe- *Viscum album* L. (Loranthaceae),
- Mug-wet- *Asperula odorata* L. (Lamiaceae),
- Mug-wet- *Asperula odorata* L. (Lamiaceae),
- Mustard- *Brassica juncea* L. (Brassicaceae),
- Mustard- *Brassica juncea* L. (Brassicaceae),
- Myrtle- *Myrtus communis* L. (Myrtaceae),
• Nutwood- Corylus avellana (L.) H.Karst. (Betulaceae),
• Old-maid's-pink- Saponaria officinalis L. (Caryophyllaceae),
• Omum plant- Carum carvi L. (Apiaceae),
• Paul's-betony- Veronica officinalis L. (Scrophulariaceae),
• Parsley- Petroselinum hortense L. (Apiaceae),
• Persian berry- Rhamnus frangula L. (Rhamnaceae),
• Pipe tree- Siringa vulgaris L. (Oleaceae),
• Potato vine- Solanum tuberosum L. (Solanaceae),
• Pumpkin- Cucurbita pepo L. (Cucurbitaceae),
• Quince tree - Cydonia oblonga Mill. (Rosaceae),
• Rattlebox- Rhinanthus crista-galli L. (Orobanchaceae),
• Sailor's geranium- Lamium album L. (Lamiaceae),
• Seabuckthorn- Hippophaë rhamnoides L. (Elaeagnaceae),
• Selleria- Selleria officinalis (L.) Trevis. ex Briq. (Lamiaceae).
• Sea-buckthorn- Hippophaë rhamnoides L. (Elaeagnaceae),
• Serpent grass- Polygonum bistorta L. (Polygonaceae),
• Sea-buckthorn- Hippophaë rhamnoides L. (Elaeagnaceae),
• Serpent grass- Polygonum bistorta L. (Polygonaceae),
• Sea-buckthorn- Hippophaë rhamnoides L. (Elaeagnaceae),
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• Sea-buckthorn- Hippophaë rhamnoides L. (Elaeagnaceae),
• Serpent grass- Polygonum bistorta L. (Polygonaceae).
Conclusion

Thus, the evaluation of traditional and indigenous medicine experience in Russia, Belarus, Ukraine we have conducted allowed us to determine the most commonly used medicinal plants of hypoglycemic action, which can be promising sources of phytonutrients for development of optimized anti-diabetic special foods for patients suffering from diabetes mellitus. The results of this study suggest that food industry specialists and nutritionists should consider the issue of developing special foods with significant biological activity and good application properties based on edible and medicinal plants traditionally applied for treatment.

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References
