World Journal of Nutrition and Health 2019, Vol. 7, No. 1, 18-22
Available online at http://pubs.sciepub.com/jnh/7/1/4
Published by Science and Education Publishing
DOI:10.12691/jnh-7-1-4

Antidiabetic Herbs and Spices

ADENIYI Paulina O.[1,*], SANUSI Rasaki A.[2]

[1]Institute of Agricultural Research and Training, Obafemi Awolowo University, Apata, Ibadan, Nigeria
[2]Department of Human Nutrition, University of Ibadan, Ibadan, Nigeria
*Corresponding author: doyinadeniyi@yahoo.com

Received April 22, 2019; Revised June 19, 2019; Accepted July 01, 2019

Abstract The increasing prevalence of diabetes mellitus is gradually becoming a public health threat globally. Most existing therapeutic regimens are not without limitations and constraints, hence, the need for easy, feasible and cost effective alternative cannot be overemphasized. Some herbs and spices have been observed to exert antidiabetic activity. This review therefore compiles antidiabetic herbs and spices with the places of origin, conditions for growth, culinary uses and mechanisms of action of the antidiabetic effect with a view of encouraging their possible use as an antidiabetic food adjunct in cuisines towards the prevention and management of the diabetes. The search engines accessed were Google Scholar, Scopus, HINARI and PubMed. Antidiabetic herbs and spices compiled include; African nutmeg, Basil, Cinnamon, Cloves, Coriander, Cumin, Curry leaves, Dandelion, Dill, Fenugreek seeds, Garlic, Ginger, Mustard seed, Nutmeg, Onion, Rosemary and Turmeric. Some of these are most suitable only in savoury dishes while others are applicable in both sweet and savoury dishes. The possible mechanisms of the antidiabetic activity are: inhibition of the activities of α-amylase, α-glucosidase, hexokinase, Dipeptidyl peptidase-4 (DPP-4), glycogenolytic and gluconeogenic enzymes; activation of antioxidant enzymes, Adenosine monophosphate-activated protein kinase (AMPK); free radical scavenging activity; mimicry of insulin action; enhancement of insulin secretion; enhancement of Glucose transporter-4 (GLUT-4) translocation and antiplatelet activity. Some herbs and spices are indeed antidiabetic. However, their application in cuisines could be an easy, feasible and cost effective measure to prevent and manage diabetes globally.

Keywords: *diabetes, herbs, spices, mechanism of action*

Cite This Article: Adeniyi Paulina O., and SANUSI Rasaki A., “Antidiabetic Herbs and Spices.” *World Journal of Nutrition and Health*, vol. 7, no. 1 (2019): 18-22. doi: 10.12691/jnh-7-1-4.

1. Introduction

The prevalence of diabetes mellitus, which has been identified as a ‘”disease of comfort” or “civilization disease”, is increasing globally. The global prevalence of diabetes among all age groups was estimated to be 2.8% (equivalent to 171 million people) in 2000 and this was projected to increase to 4.4% (equivalent to 366 million people) in 2030 [1]. The reports of Shaw et al, [2] and Whiting et al., [3] corroborated this. The global prevalence of diabetes among adults between 20-79 years was 6.4% (285 million adults) in 2010 and this was projected to increase to 7.7% (439 million adults) in 2030 [2] while in 2011 there were 366 million people (all age groups) with diabetes and this was expected to rise to 552 million in 2030 [3].

Existing diabetic therapeutic regimens are known not to be without limitations some of the undesireable side effects of which include weight gain [4], hypoglycaemia risk or shock [5], dyspepsia, nausea, vomiting [6] amongst others.

For culinary use herbs and spices are included in food to enhance flavour, colour, appearance, taste and sometimes texture of the food. If the part of the plant used are the leaves it is called a herb while it is a spice if other parts such as roots, barks or seeds are used. Exploration of the culinary use of antidiabetic herbs and spices may be an easy, feasible and cost effective alternative to prevent and manage diabetes throughout the world. This review therefore compiles the origin, growth conditions, culinary uses and mechanisms of action of some antidiabetic herbs and spices with a view of encouraging their use in cuisines towards reducing the prevalence of diabetes globally.

2. Methodology

The search engines accessed included Google Scholar, Scopus, HINARI and PubMed.

2.1. African Nutmeg (*Monodora myristica*)

African nutmeg also known as calabash nutmeg is a native of evergreen forests of West and Central Africa. The seeds are used as spice in both savoury and sweet dishes [7]. It is commonly seen grown wild in evergreen forest and it does not always produce fruit when cultivated because of the unavailability of the beetle that normally pollinates them in the wild [8]. The inhibitory effect of ethanolic extract of African nutmeg on α-amylase is one of the possible mechanisms of its antidiabetic activity; hence, it may reduce glucose digestion and subsequently lowers postprandial glucose [9].

2.2. Basil (*Ocimum basilicum*)

Basil is native to tropical Africa and West South East Asia and is now cultivated in different parts of the world that favour its growth. Basil is sensitive to cold and grows best in hot, dry conditions, hence, it may be cultivated in temperate zones and sub-tropical climates. The leaves are used as culinary herbs mostly in savoury dishes but when steeped in cream or milk may be applicable in ice cream and similar cold desserts. It is commonly added as the last ingredient due to the volatility of its aromatic flavour. It complements beautifully with onion, garlic and olives [10]. The antidiabetic effect of Basil is exerted via enhancing the translocation of Glucose transporter-4 to plasma and cell membranes [11] and inhibition of α-glucosidase and α-amylase activities [12].

2.3. Cinnamon (*Cinnamomum spp*)

Cinnamon is obtained from the bark of several tree species of the genus *Cinnamomum* and ground into powder to be used as spice. *Cinnamomum verum* is sometimes considered to be the true cinnamon. It is native to Ceylon in Sri Lanka but now Indonesia, China, Vietnam and Burma are notable producers. Humid tropical evergreen rainforest conditions with well-drained, sandy soil rich in humus best favours the growth of cinnamon. Cinnamon is of wide application in cuisines and is mostly suitable for both savoury and sweet dishes. A possible mechanism of the antidiabetic activity of cinnamon is via the inhibition of α-amylase, α-glucosidase and lipase activities [13] while cinnamon (*Cinnamomum zeylanicumon*) powder supplementation in diet increased the activity of antioxidant enzymes (Glutathione peroxidise, catalase and superoxide dismutase) thus preventing diabetic complications due to diabetes-induced oxidative stress in alloxan-induced diabetic rats [14].

2.4. Cloves (*Syzygium aromaticum*)

Cloves are native of Maluku Islands in Indonesia and are the aromatic flower buds of a tree of the family Myrtaceae. Cultivation requires humid tropical and sub-tropical climatic conditions with optimum temperature of around 70-85°F (20-30°C). It is applicable in most savoury and sweet dishes [15]. The antidiabetic effect of clove is traceable to its ability to inhibit the activity of α-amylase markedly (T16) while clove aqueous extract lowered blood glucose via mimicry of insulin action and inhibition of the activities of phosphoenol pyruvate carboxykinase (PEPCK) and glucose-6-phosphatase (G6Pase) through reduction of gene expression [17].

2.5. Coriander (*Coriandrum sativum*)

Coriander is an annual herb native to Southern Europe and North Africa. It can grow well in both temperate and tropical frost-free climates, does not grow well in heavy clay soil and does not need much fertilizer [18]. For culinary purposes, the leaves are used as garnishes and culinary herbs in most savoury dishes while the seeds are used as spice in sweet dishes. Ethanolic extract of coriander leaves was observed to restore viability of destroyed pancreas in alloxan-induced diabetic mice while it inhibited the activity of α-glucosidase in vitro [19]. Coriander seeds reduced elevated biomarkers of metabolic syndrome and artherosclerosis and increased cardio-protective indices in obese hyperglycaemic-hyperlipidemic Meriones shawi rats [20].

2.6. Cumin Seeds (*Cuminum cyminum*)

Cumin is a native of Iran and the Mediterranean. It is grown in cooler climates in spring and requires fertile, well-drained soil. It is used as spice in many savoury dishes and is a staple ingredient in curry powder and many spice blends. The antidiabetic effect of cumin seeds was exerted through enhancement of insulin secretion and the amelioration of diabetes-induced oxidative stress by exhibiting free radical scavenging activity in streptozocin-induced diabetic rats [21].

2.7. Curry Leaves (*Murraya koenigii)*

Curry tree is native to India. It is a tropical and sub-tropical plant and the cultivation has spread to different parts of the world suitable for its growth. The leaves are mostly used as culinary herbs in savoury dishes. Aqueous extract of curry leaves restored the viability of the degenerated kidney and Islets of Langerhans in streptozocin-induced diabetic rats thus lowering blood glucose and improving weight gain [22]. In the same vein, Gangwar and Rao, [23] reported the antidiabetic effect of powdered curry leaves which was achieved via inhibition of hexokinase, glucose-6-phosphatase and fructose 1,6-bi phosphatase activities, enhancement of insulin secretion and C-peptide resulting into reduced blood glucose and glycated haemoglobin.

2.8. Dandelion (*Taraxacum officinale*)

Dandelion is a large genus of flowering plants in the family Asteraceae. It is native to Eurasia and North America. It is a hardy, short-lived perennial that is capable of growing anywhere regardless of soil conditions and is found growing in many temperate regions of the world. The leaves are used as culinary herbs in savoury dishes, garnishes, accompaniment, salads and wine production while the flowers can be processed into jam [24]. Different isolates of *Taraxacum officinale* exhibited inhibitory effect on α-glucosidase in vitro [25] as well as α-amylase [26].

2.9. Dill (*Anethum graveolens*)

Dill is an annual herb in the celery family Apiaceae. It is native to Mediterranean region and Russia. It grows best at soil temperature of between 60-70°F (15-22°C) and requires rich soil. Dill leaves are used as culinary herbs while the seeds are used as spice mainly in savoury dishes but sometimes in some milk and yoghurt dishes. Aqueous extracts of dill leaves and seeds prevented diabetic complication and ameliorated diabetic state via free radical scavenging activity, prevention of the formation of advanced glycation end products (AGEs) and fructosamine as well as the reduction of protein carbonyl and thiol groups oxidation [27].

2.10. Fenugreek Seeds (*Trigonella foenum-graecum*)

Fenugreek is a fragrant annual plant of the family Fabaceae, It is native to southern Europe and the Mediterranean region. The most suitable growing conditions for fenugreek are warm to hot climate with temperature range of 50-90°F (10-32°C) and for optimum seed production it is advisable to grow it in spring or early summer [28]. Its fragrant leaves are used as culinary herbs while the aromatic flavourful seeds are applicable as spice mostly in savoury dishes. The seed powder is also a staple ingredient in curry powder, many spice blends and tea blends [29]. Many scientific studies have established the antidiabetic effect of fenugreek and this was channelled through the inhibition of pancreatic lipase and α-amylase activities [30,31], notable free radical scavenging activity as well as enhancement of glucose uptake by 3T3-L1 cell lines [32].

2.11. Garlic (*Allium sativum*)

Garlic is native to Central Asia. Extremely high temperatures are not suitable for garlic growth and the optimum temperature range for growth is 12-34°C in fertile, well-drained light soil (clay should be avoided) [33]. The pungent flavour of garlic cloves makes it only suitable for savoury dishes. Inhibition of the activities of angiotensin-converting enzyme, α-amylase and α-glucosidase as well as notable free radical scavenging activity [34].

2.12. Ginger (*Zingiber officinale*)

Ginger originated from Southern Asia. It is now cultivated in different parts of the world suitable for its growth. The optimum conditions for ginger growth is warm and humid climate in well-drained soils such as sandy, clay, red loam, lateritic loam and friable loam which is rich in humus. Fertility is a necessary soil requirement [35]. It is of interest to note that the culinary use of ginger is versatile since it is applicable and suitable for almost all dishes both savoury and sweet. Ginger exerts its antidiabetic effect via enhancement of insulin secretion [36] and mimicry of insulin action in enhancing glucose uptake by the muscle and adipose of normal and diabetic rats [37].

2.13. Mustard Seed (*Brassica spp)*

Mustard is a native of tropical regions of North Africa, temperate regions of Europe and some parts of Asia. It is an annual plant best cultivated in well-drained soil and thrives well in sandy and loam soil with varying pH from acid, neutral to alkaline (4.9-8.2). It can even grow in high acid soil and is adaptable to a wide variety of climatic conditions with temperature range 6-27°C [38]. The seed is used as spice and condiment mostly in savoury dishes. The possible mechanism of the antidiabetic effect of mustard seed is via activation of glucose synthetase thus enhacing glycogenesis, inhibiting the activity of gluconeogenic enzymes and glycogen phosphorylase thus reducing hepatic production of glucose [39]. Another possible mechanism of action is by enhancing insulin secretion [40].

2.14. Nutmeg (*Myristica fragrans*)

Nutmeg is native to the Spice Islands (Moluccas) in Indonesia. It is a tropical evergreen tree belonging to the family Myristicaceae. Nutmeg thrives well in tropical climate with humid conditions, temperature range 77-95°F (25-35°C), not less than 60 inches annual rainfall and clay loam, sandy loam and red laterite soil. It can be propagated both sexually and asexually [41]. Two spices can be derived from the fruit; nutmeg from its seed and mace from the seed covering but the former is more popular in use than the latter. Nutmeg is applicable in many kinds of baked foods, confections, puddings, meat sausages etc; hence, it is suitable for many savoury and sweet dishes. Mace is similar to nutmeg in its culinary uses. The blood glucose lowering effect of nutmeg was achieved by improving insulin sensitivity via functional activation of peroxisome proliferator-activated receptors (PPARs) which enhanced 3T3-L1 preadipocytedifferentiation, regulation of target genes and protein expression and enhancing GLUT-4 translocation (42).

2.15. Onion (*Allium cepa*)

Onion is a biennial plant belonging to the family Amaryllidaceae. It is native to Southwest Asia and is now grown worldwide in places suitable for its growth. It does not thrive well in regions with excessive heat, cold and rainfall but grows under a wide range of climatic conditions. The bulb is versatile in use in savoury dishes and it also tenderises food. The antidiabetic effect of onion has been established by various scientific reports and the possible mechanism of action is by its markedly notable antioxidant and antiplatelet aggregation activities thus preventing diabetes complication [43] as well as inhibition of the activity of α-glucosidase and free radical scavenging activity [34].

2.16. Rosemary (*Rosmarinus officinalis*)

Rosemary is a perennial herb related to the mint or Lamiaceae family. It is native to the Mediterranean regions and thrives well in warm and moderately dry climates with average temperature range 68-86°F (20-30°C. It needs at least 6-8 hours of daily sun exposure [44]. The needle-like leaves are used as culinary herbs mainly in savoury dishes specifically meat, poultry, fish and related food products. A notable mechanism of the blood glucose lowering effect of rosemary is on its ability to regulate incretins which are hormones that augment secretion of insulin after food consumption thus enhancing glucose uptake and lowering hepatic blood glucose. Rosemary exerts inhibitory action on Dipiptidyl peptidase-4 (DPP-4) which breaks down incretins and makes them available to serve their purpose in the body [45] Another possible mechanism of action is the activation of 5' Adenosine monophosphate-activated protein kinase (5'AMPK) which enhances glucose uptake in skeletal muscle thus improving insulin sensitivity [46].

2.17. Turmeric (*Curcuma longa*)

Turmeric was believed to have originated from Southern East Asia.It belongs to the ginger family which is Zingiberaceae. It is a tropical rhizomatous, herbaceous perennial plant. Optimum temperature for growth is between 68 and 86°F (20 and 30°C) and it requires warm and humid climatic conditions, annual rainfall of at least 1500mm and does not thrive well in water stagnation and alkalinity [47]. The root is use as spice in cooking exerting a mustard-like, pungent and earth aroma. It is suitable for savoury and sweet dishes while the leaves are used only in sweet dishes [48]. The high potency of turmeric in free radical scavenging activity is markedly one of the possible mechanisms of its antidiabetic activity, hence, it may prevent diabetes complications which may result from diabetes-induced oxidative stress [49]. Furthermore, it also exerts inhibitory effect on α-amylase activity [50].

3. Conclusion

The herbs and spices compiled are indeed antidiabetic food adjuncts and the culinary application of these may be an easy, feasible and cost effective measure to prevent and manage diabetes globally.

References

[1] Wild S., Roglic G., Green A., Sicree R., and King H. (2004). Global prevalence of diabetes: Estimates for the year 2000 and projection for 2030. Diabetes Care; 27(5): 1047-1053.

[2] Shaw J.E., Sicree R.A. and Zimmet P.Z. (2010). Global estimates of the prevalence of diabetes for 2010 and 2030. Diabetes Research and Clinical Practice; 87(1): 4-14.

[3] Whiting D.R., Guariguata L., Weil C. and Shaw J. (2011). IDF Diabetes Atlas: Global estimates of the prevalence of diabetes for 2011 and 2030. Diabetes Research and Clinical Practice; 94(3): 311-321.

[4] Russell-Jones D.and Khan R. (2007), Insulin-associated weight gain in diabetes- causes, effects and coping strategies. Diabetes, Obesity and Metabolism; 9(6): 799-812.

[5] Ratner R.E., Gough S.C.L., Mathieu C., Prato S.D., Bode B., Mersebach H. et al., (2013). Hypoglycemia risk with insulin degludec compared with insulin glargine in type 2 and type 1 diabetes: a pre-planned meta-analysisof phase 3 trials. Diabetes, Obesity and Metabolism; 15(2): 175-184.

[6] Tillner J., Posch M.G., Wagner F., Teichert L., Hijazi Y., Einig C., et al (2019). A novel dual glucagon-like peptide and glucagon receptor agonist SAR425899: Results of randomized, placebo-controlled first-in-human and first-in-patient trials. Diabetes, Obesity and Metabolism; 21(1): 120-128.

[7] Weiss E.A. (2002). Spice crops. CABI Publishing, England, pp102-103.

[8] Barwick M. (2004). Tropical and Subtropical Trees- A worldwide Encyclopaedia Guide. Thames and Hudson, London.

[9] Okonji R.E., Akinwumi K.F., Madu J.O., Bamidele F.S. and Funmilola A. (2014). In vitro study on α-amylase inhibitory activities of Digitaria exilis, Pentadiplandra brazzeana (Baill) and Monodora myristica. International Journal of Biological and Chemical Sciences; 8(5): 2306-2313.

[10] Markinen S.M. and Paakkonen K.K. (1999). Processing and use of Basil in foodstuffs, beverages and in food preparation, In Basil: The Genus Ocimum. Harwood Academic Publishing, United Kingdom, pp 142-157.

[11] Kadan S., Saad B., Sasson Y. and Zaid H. (2016). In vitro evaluation of antidiabetic activity and cytotoxicity of chemically analysed Ocimum basilicum extracts. Food Chemistry; 196(1): 1066-1074.

[12] El-Beshbishy H.A. and Bahashwan S.A. (2012). Hypoglycemic effect of basil (Ocimum basilicum) aqueous extract is mediated through inhibition of α-glucosidase and α-amylase activities: An in vitro study. Toxicology and Industrial Health; 28(1): 42-50.

[13] Lin G.M., Hsu C.Y. and Chang S.T. (2018). Antihyperglycemic activities of twig extract of indigenous cinnamon (Cinnamomum osmophloeum) on high-fat diet and streptozocin-induced hyperglycaemic rats. Journal of the Science of Food and Agriculture; 98(15): 5908-5915.

[14] Beji R.S., Khemir S., Wannes W.A., Ayari K. and Ksouri R. (2018). Antidiabetic, antihyperlipidemic and antioxidant influences of the spice cinnamon (Cinnamomum zeylanicumon) in experimental rats. Brazilian Journal of Pharceutical Science; 54(2).

[15] Milind P. and Deepa K. (2011). Clove: A champion spice. International Journal of Research in Ayurveda and Pharmacy; 2(1): 47-54.

[16] Tahir H.U., Sarfraz R.A., Ashraf A. and Adil S. (2016). Chemical composition and antidiabetic activity of essential oils obtained from two spices (Syzygium aromaticum and Cuminum cyminum). International Journal of Food Properties; 19(10): 2156-2164.

[17] Prasad R.C., Herzog B., Boone B., Sims L. and Law M.W. (2005). An extract of Syzygium aromaticum represses genes encoding hepatic gluconeogenic enzymes. Journal of Ethnopharmacology; 96(1-2): 295-301.

[18] Carrubba A., la Torre R. and Calabrese I. (2002). Cultivation trials of coriander (Coriandrum sativum L.) in a semi arid Mediterranean environment. Acta Hortic; 576: 237-242.

[19] Aligita W., Susilawati E., Septiani H. and Atsil R. (2018). Antidiabetic activity of coriander (Coriandrm sativum L.) leaves' ethanolic extract. International Journal of Pharmaceutical and Phytopharmacological Research; 8(2): 59-63.

[20] Aissaoui A., Zizi S., Israili Z.H., and Lyoussi B. (2011). Hypoglycemic and hypolipidemic effects of Coriandrum sativum L. in Meriones shawi rats. Journal of Ethnopharmacology; 137(1): 652-61.

[21] Mohamed D.A., Hamed I.M. and Fouda K.A. (2018). Antioxidant and antidiabetic effect of cumin seeds crude ethanol extract. Journal of Biological Sciences; 18: 251-259.

[22] Al-Ani I.M., Santosa R.I., Yankuzo M.H., Saxena A.K. and Alazzawi K.S. (2017). The antidiabetic activity of curry leaves (Murraya koenigii) on the glucose levels, kidneys and islets of Langerhans with streptozocin-induced diabetes. Makara Journal of Health Research; 21(2): 54-60.

[23] Gangwar R. and Rao C.H. (2017). Antidiabetic efficacy of Murraya koenigii in streptozocin-induced diabetes mellitus in albino Wistar rats. Journal of Scientific Research in Allied Sciences; 3(6): 442-451.

[24] Escudero N.L., De Arellano M.L., Fernandez S., Albarracih G. and Mucciarelli S. (2003). Taraxacum officinale as a food source. Plnt Foods for Human Nutrition; 58(3): 1-10.

[25] Choi J., Yoon K.D. and Kim J. (2018). Chemical constituents from Taraxacum officinale and their α-glucosidase inhibitory activities. Bioorganic and Medicinal Chemistry Letters; 28(3): 476-481.

[26] Mir M.A., Sawhney S.S. and Jassal M.M.S. (2015). In vitro antidiabetic studies of various extracts of Taraxacum officinale. The Pharma Innovation; 4(1): 61-66.

[27] Oshaghi E.A., Khodadadi I., Tavilani H. and Goodarzi M.T. (2016). Aqueous extract of Anethum graveolens L. has potential antioxidant and antiglycation effects. Iranian Journal of Medical Sciences; 41(4): 328-333.

[28] Mehrafarin A., Rezazadeh S., Naghdi B.H., Noormohammadi G., Zand E. and Qaderi A.A. (2011). A review on biology, cultivation and biotechnology of fenugreek (Trigonella foenum-graecum) as a valuable medicinal plant and multipurpose. Journal of Medicinal Plants; 1(37): 6-24.

[29] Charles D.J. (2012). Antioxidant properties of spices, herbs and other sources. In: Fenugreek. Sprringer, New York, U.S.A. pp 295-303.

[30] Herrera T., del Hierro J.N., Fornari T., Reglero G. and Martin D. (2019). Inhibitory effect of quinoa and fenugreek extracts on pancreatic lipase and α-amylase in vitro traditional conditions and intestinal stimulated conditions. Food Chemistry; 270(1): 509-517.

[31] Fernando W.T., Attanayake A.M.K.C., Perera H.K.I., Sivakanesan R., Jayasinghe L., Araya H. and Fujimoto Y. (2019). Isolation, identification and characterization of pancreatic lipase inhibitors from Trigonella foenum-graecum seeds. South African Journal of Botany; 121: 418-421.

[32] Hajra D. and Paul S. (2018). Study of glucose uptake enhancing potential of fenugreek (Trigonella foenum-graecum) leaves extract on 3T3-L1 cells line and evaluation of its antioxidant potential. Pharmacognosy Research; 10(4): 347-353.

[33] Kamenetsky R. (2007). Garlic: Botany and Horticulture. In: Horticulture Reviews, Ed. Janick J.. John Wiley and Sons Publishing, New Jersey, U.S.A. Volume 33; p 123-138.

[34] Oboh G., Ademiluyi A.O., Agunloye O.M., Ademosun A.O. and Ogunsakin B.G. (2018). Inhibitory effect of garlic, purple onion and white onion on key enzymes linked with type 2 diabetes and hypertension. Journal of Dietary Supplements.

[35] Chongtham T., Chatterjee K., HYNANITE V., Chattopadhyay P.K. and Khan S.A. (2013). Ginger (Zingiber officinale Rosc.) germplasm evaluation for yield and quality in southern West Bengal .Journal of Spices and Aromatic Crops; 22(1): 88-90.

[36] Adeniyi P.O., Sanusi R.A. and Obatolu V.A. (2014). Effect of raw and cooked ginger (Zingiber officinale) extracts on serum insulin in normal and diabetic rats. International Journal of Clinical Nutrition; 2(4): 69-73.

[37] Adeniyi P.O., Sanusi R.A. and Obatolu V.A. (2017). Dietary ginger extracts enhanced glucose uptake by muscle and adipose of normal and diabetic rats via mimicry of insulin action. American Journal of Biomedical Research; 5(3): 46-56.

[38] Shekhawat K., Rathore S.S., Premi O.P., Kandpal B.K. and Chauhan J.S. (2012). Advances in agronomic management of Indian mustard (Brassica juncea L.): An overview. International Journal of Agronomy; 2012.

[39] Khan B.A., Abraham A. and Leelamma S., (1995). Hypoglycemic action of Murraya koenigii (curry leaf) and Brassica juncea (mustard): mechanism of action. Indian Journal of Biochemistry and Biophysics; 32(2): 106-108.

[40] Thirumalai T., Therasa S.V., Elumalai E.K. and David E. (2011). Hypoglycemic effect of Brassica juncea seeds on streptozocin-induced diabetic male albino rats. Asian Pacific Journal of Tropical Biomedicine; 1(4): 323-325.

[41] Brixius D. (2018). A hard nut to crack: nutmeg cultivation and the application of natural history between the Maluku islands and Isle de France (1750s-1780s). The British Journal for the History of Science; 51(4): 585-606.

[42] Muchtarich M., Low K. and Lestari K. (2016). The in silico study of nutmeg seeds (Myristica fragrans Houtt) as peroxisome proliferator activated receptor gamma activator using 3D-QSAR pharmacophore modelling. Journal of Applied Pharmaceutical Science; 6(9): 48-53.

[43] Ko E.Y., Nile S.H., Tung Y.S. and Keum Y.S. (2018). Antioxidant and antiplatelet potential of different methanol fractions and flavolols extracted from onion (Allium cepa L.). Biotechnology; 8: 155. doi.org/10.1007/s13205-018-1184-4.

[44] Gavan-Capararros P., Llanderal A., Rodriguez J.C., Maksimovic I., Urrestarazu M. and Lao M.T. (2018). Rosemary growth and nutrient balance: leachate fertigation with leachates versus conventional fertigation. Scientia Horticulture; 242(19): 62-68.

[45] Salim B., Hocine A. and Said G. (2017). First study on antidiabetic effect of Rosemary and Salvia by using molecular docking. Arabian Journal of Medicinal and Aromatic Plants; 5(6): 56-71.

[46] Naimi M., Vlavcheski F., Murphy B., Hudlicky T. and Tsiani E. (2017). Carnosic acid as a component of rosemary extract stimulates skeletal uscle cell glucose uptake via AMPK activation. Clinical and Experimental Pharmacology and Physiology; 44(1): 94-102.

[47] Choudhary V.K. and Sureshkumar P. (2019). Weed suppression, nutrient leaching, water use and yield of turmeric (Curcuma longa L.) under different land configurations and mulches. Journal of Cleaner Production; 210: 795-803.

[48] Prasad S. and Aggarwal B.B. (2011). Turmeric, the golden spice. In : Traditional medicine to modern medicine. Taylor and Francis Publishing, England, United Kingdom. Chapter 13, pp 843-917.

[49] Wojcik M., Krawczyk M. and Wozniak L.A. (2018). Antidiabetic activity of curcumin: insight into its mechanisms of action. Nutritional and Therapeutic Interventions for Diabetes and Metabolic Syndrome; 2: 385-401.

[50] Pujimulyani D., Yahanto W.A., Setyawati A., Arumwardana S, Amalia A., Annisa K. et al. (2018). Amylase inhibition and free radical scavenging activities of white turmeric extract and fractions. Journal of Food Technology and Industry; 29(1): 10-18.