Effect of the consumption of natural products on some biochemical parameters of a type 2 diabetic population

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Abstract

Purpose The use of phytotherapy is common worldwide and especially in Algeria. This practice was transmitted orally and ritually to treat chronic diseases. Safe extracts of edible plants can provide a resource of structurally diverse molecules that can effectively interfere with multifactorial diseases, such as diabetes mellitus. The objective of this work is to study the biochemical parameters of diabetic populations who consume medicinal plants.

Methods This study involved 100 T2D subjects, recruited over a five-month period via a questionnaire containing anthropometric information: sex, age, age of diabetes, type of diabetes, plants consumed. Recruited patients were recalled for further examination of the biochemical record (fasting glucose, glycated hemoglobin, total cholesterol, triglycerides, creatinine, ASL and ASP).

Results We found that diabetic patient associated with prescribed medical treatment uses the medicinal plants. This use is strongly predominant by women in both populations with 76% of them using herbal medicine. 58% of diabetics under herbal medicine had slightly unbalanced diabetes with HbA1c > 7. The difference between the total cholesterol, ASL and ASP parameters of the two populations was not significant. The study of correlation showed that the consumption of plant had an effect on the type of correlation between biochemical parameters of diabetic patients.

Conclusions The consumption of medicinal plants did not affect the values of the measured biochemical parameters, while the correlation between these parameters can be modified.

Keywords Diabetes · Medicinal plants · Biochemical parameters · Correlation

Introduction

Diabetes mellitus (DM) is becoming a hot topic because it is a metabolic disease with no clinical symptoms, but a number of complications are more common to patients with type 2 diabetes (T2D). The World Health Organization therefore, considers T2D as a public health problem because of its epidemic progression [1]. The cost of this disease represents between 2.5 and 15% of annual national budgets allocated to health [2].

DM is a chronic disease, and its complications are a source of very important needs in terms of care and follow-up care. It is characterized by multiple defects in its pathophysiology and

abnormalities in carbohydrates, lipids proteins, and metabolism [3, 4]. It is clear that this disease leads to hyperglycemia and to many other complications such as hyperlipidemia, hypertension, atherosclerosis, retinopathy, neuropathy, and nephropathy [5, 6].

The prohibitive costs for who have difficulty to use modern medicines, direct patients to traditional medication (WHO, 2016). As a result, many diabetics, based on their popular culture, ritually use herbal medicine to reduce the daily dose of antidiabetic therapy and, also, to moderate the cost of management of the disease [3]. According to some ethnopharmacological studies, several medicinal plants are used in this context. Extracts from edible biomaterials have become a major focus of nutritional research to develop functional food and nutraceuticals with proven health benefits and good safety profiles [7]. It is probable that the biochemical parameters can be altered by alimentary diet. A higher intake of total bread and total bread-rice was associated with Fasting blood glucose [8]. Some researchers have shown that the

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consumption of plant extracts can affect biochemical parameters. According to Almalki et al., (2019) [9], a significant increase in the value of serum glucose and decline of insulin value were observed in rats. Several alterations of lipid and protein profile and oxidative stress markers were noted in diabetic control rats treated by the extracts of the following three plant: *Olea oleaster* (Oleaceae family) leaves (OLE), *Juniperus procera* (Cupressaceae family) leaves (JLE), and *Opuntia ficus-indica* (Cactaceae family) stems (OSE). The obtained results showed that OLE, JLE, and OSE attenuated the physiological alterations. These new data show that the attenuation influences of OLE, JLE, and OSE attributed to their antioxidant properties confirmed by oxidative stress markers evaluation.

In their research in insulin-resistant high-fat diet-fed mice, Weidner et al., [10] showed that the ethanolic extract of *Melissa officinalis* is effective to prevent or concomitantly treat T2D and associated disorders such as dyslipidemia and hypercholesterolemia. In another study, the use of *Melissa officinalis* was effective in remission of LDL and AST levels in patients with borderline hyperlipidemia [11]. Herbs are considered as a rich source of Phenolic compounds. These compounds are secondary metabolites that are widely distributed in edible and inedible plants [11, 12]. They received considerable attention owing to their antioxidant activity and free radicals scavenging abilities [13]. However, although it is a natural therapy, herbal medicine is not without risk [14, 15].

The aim of this study is to verify the place of phytotherapy in the modification of the biochemical parameters of a type 2 diabetic population from Tlemcen (Algeria) region.

Material and methods

Type of survey and data collection

To carry out our work, we conducted a descriptive case-control study with recruitment in one phase. The study focused on a population of the wilaya of Tlemcen (Algeria) and was spread over a period of 5 months (January–May 2019).

It is a non-experimental, observational, descriptive study. The study concerned patients with type 2 diabetes. It was conducted using a questionnaire prepared by ourselves and given to the treating physicians to recruit the subjects of the survey at the time of their visits in medical practices (medical internists, family doctors and general practitioners) in the Tlemcen region.

The questionnaire allowed us to have the general anthropometric information (sex and age type of diabetes). The recruited patients were recalled to the laboratory of the Tlemcen University Hospital for a complementary examination of the biochemical balance (fasting glucose, glycated hemoglobin, Creatinine, total cholesterol, ASL and ASP).

Population and sample size

The study population contained 100 type 2 diabetic patients and 10 controls. The recruitment concerned all the patients diagnosed like diabetic of type 2. The criteria of inclusion and exclusion were fixed as follows:

Inclusion criteria

We included in our study patients:

- Type 2 diabetics of both sexes.
- Aged 18 and over.
- Under treatment with metformin.
- Who gave their consent to participate.

Exclusion criteria

It was excluded from this study.

- Patients with type 1 diabetes.
- Secondary diabetes and gestational diabetes.
- Patients who have not answered to the calls.
- Patients with an incomplete questionnaire.

The witnesses were recruited at the time of the consultation for a reason other than diabetes.

Biochemical parameters assaying

The biochemical parameters targeted in this study are fasting glucose, glycated hemoglobin, total cholesterol, triglycerides, creatinine, ASL and ASP. After 12–14 h of fasting, 10 mL sample of venous blood was taken from each patient in our laboratory at the beginning and end of the study. The centrifuge of samples was performed for 10 min at the room temperature and at 3000 rpm to separate serum. FBG was assessed using an enzymatic (glucose oxidize-peroxides) in vitro test. Serum total cholesterol, triglycerides levels were measured by enzymatic colorimetric analysis. Liver enzymes including alanine transaminase (ALT), aspartate transaminase (ASP) and creatinine were determined by kinetic UV and Jaffe colorimetric analysis respectively. All of the tests used standard enzymatic kits produced by the Sigma-Aldrich Company. The assays were carried out using an automaton for parameters Analysis. The assay of glycated hemoglobin was performed using chromatography cation exchange resin.

Analysis of parameters and method of analysis

The results obtained are presented in the form of means accompanied by the standard deviation, maximum value and minimum value. The processing and the calculation of the results, as well as the comparison between the groups and the witnesses, were carried out by the software MINITAB (16.2.3 Minitab Inc. Commonwealth, PA, USA) and Excel (Microsoft Office, 2010).

In correlation tests, we will only mention Pearson correlation coefficient values and meanings. The interpreters will follow Cohen, (1988) [16] guidelines:

- Around 0.10 effect of small size low correlation
- Around 0.30 effect of small average mean correlation
- Around 0.50 large size effect strong correlations

Results

Biochemical parameters

The results of the biochemical parameters measured for the two study populations are divided according to sex in Table 1.

We don't find any significant differences between the total means between the two populations. But according to sex, we notice that there is a difference in the values obtained between men and women for the glycated hemoglobin. All patients have above-standard blood glucose levels, where the mean is 158 mg/ dL in population 1 and 142 mg/ dL in population 2 (Table 1); these results are close to the norm. We observed a poor glycemic balance in our patients and an increase in HbA1c, more marked in men in population 1 (7.76 ± 2.01). Then this rate tends to decrease to be in the norm in population 2 (6.69 ± 1.17). Men, from population 2, showed a high triglyceride value (181 ± 55 mg/ dL).

Age distribution

Figure 1 shows the distribution of the two populations by age group. The prevalence of the disease is highest (54.55%) in population 1 adults whose age is between 61 and 75 years. This prevalence tends to decrease (46%) for patients who use the prescribed treatment and herbal medicine at the age group between 46 and 60 years old.

Distribution according to blood glucose

For fasting blood glucose, Fig. 2 shows that 84% of patients using herbal medicine had a blood glucose level above

Table 1 Biochemical parameters of the studied populations

Biochemical parameters		Average and standard error	Average and standard error
fasting glucose mg/ dL	Male	155 $\pm$ 75	138 $\pm$ 31
	Female	159 $\pm$ 51	145 $\pm$ 39
	Total	158 $\pm$ 57	142 $\pm$ 35
Glycated hemoglobin %	Male	776 $\pm$ 201	669 $\pm$ 117
	Female	707 $\pm$ 15	733 $\pm$ 12
	Total	723 $\pm$ 166	704 $\pm$ 122
Creatinine mg/ dL	Male	94 $\pm$ 22	97 $\pm$ 023
	Female	76 $\pm$ 02	91 $\pm$ 16
	Total	81 $\pm$ 022	94 $\pm$ 20
Total Cholesterol mg/ dL	Male	160 $\pm$ 050	157 $\pm$ 30
	Female	155 $\pm$ 89	156 $\pm$ 40
	Total	160 $\pm$ 104	157 $\pm$ 35
Triglyceride mg/ dL	Male	109 $\pm$ 40	181 $\pm$ 55
	Female	140 $\pm$ 53	102 $\pm$ 38
	Total	131 $\pm$ 54	110 $\pm$ 46
ASL UI/ L	Male	21.92 $\pm$ 3.45	23.4 $\pm$ 8.07
	Femmes	25.55 $\pm$ 4.43	21.83 $\pm$ 8.90
	Total	21.69 $\pm$ 4.19	21.14 $\pm$ 6.81
ASP UI/ L	Male	20.75 $\pm$ 3.47	23.4 $\pm$ 8.07
	Femmes	20.21 $\pm$ 6.05	20.25 $\pm$ 13.63
	Total	20.34 $\pm$ 6.06	21.68 $\pm$ 11.30

Fig. 1 Distribution of the populations by age

110 mg /dl while 81.8% of diabetics using the prescribed treatment had normal blood glucose level (70–110 mg/ dL). The difference between the three groups is statistically significant (≤ 0.05) (Fig. 3).

Distribution according to the glycemic equilibrium

For the glycemic balance, we see through the Fig. 3 that 58% of patients who have imbalanced diabetes ($HbA1c > 7$) had more recourse to herbal medicine. In population 1 we found a balance between the number of patients with balanced and unbalanced diabetes.

Distribution according to cholesterol value

Figure 4 represents the distribution of patients according to the cholesterol level of the two study populations. We find that patients in both populations have normal cholesterol values between 130 and 200 mg/ dL. The difference between the three groups is not statistically significant.

Distribution according to ASL / ASP parameters

Figure 5 shows the distribution of the three populations according to ASL and ASP. We find that the majority or all of the recruited patients have parameters that are in the norms.

Distribution according to the used plants

Figure 6 shows the distribution of population 2 according to the consumed plants. We note that the most used plant by the population 2 is thyme with a percentage of 54%. Olive leaves are used by 20% of patients. 20% of patients use either other plants or a mixture of plants in this case cinnamon, mint, staghorn lavender (Halhal), white mugwort (chih), Fenugreek (helba), common juniper (Elaraar).

Correlation test between the different parameters

Table 2 represents the correlation coefficients between the measured biochemical parameters of populations 1

Fig. 2 Distribution of Patients by Venous Blood Glucose

Fig. 3 Distribution of diabetics of the populations by HbA1c value

and 2. In population 1, we note that there is a significant positive correlation between blood glucose and triglycerides ($p \leq 0.05$), blood glucose and HbA1c ($p = 0.077$), ASL and ASP ($p \leq 0.05$) and a correlation significant negative between cholesterol and creatinine ($p = 0.068$), ASL and HbA1c ($p \leq 0.05$). In population 2 we found a significant positive correlation between blood glucose and creatinine ($p \leq 0.05$), blood glucose and HbA1C ($p \leq 0.05$), creatinine and triglycerides ($p = 0.079$) and ASL and ASP ($p \leq 0.05$) and a significant negative correlation between blood glucose and ASL ($p \leq 0.05$), blood glucose and cholesterol ($p = 0.068$).

By comparing the correlations of the two populations, we find that 8 parameters have changed their correlation. These parameters are blood sugar and creatinine, blood glucose and ASL, blood glucose and cholesterol, creatinine and cholesterol, blood sugar and triglycerides, creatinine and triglycerides and ASL and HbA1c.

We can say that the consumption of plants has had an effect on the type of correlation between the biochemical parameters of diabetic patients.

Discussion

Type 2 diabetes is considered as one of the scourges of the 3rd millennium. The number of people with diabetes is alarmingly high, and it is estimated that this number will rise to 552 million in 2030 [17]. It is admitted that the major problem of diabetes is not the high mortality but especially the complications related to it. If the glucose in the blood remains high over time, it can damage the functioning of several organs: the kidneys (nephropathy), the eyes (retinopathy), the neurological system (neuropathy), the heart (infarction), the blood vessels (hypertension, arteriosclerosis, stroke [AVC], ...etc. [18].

The impact of this pathology on the health system is heavy both in terms of treatment costs and the management of complications. The mission of the doctors is therefore, to treat and not cure this disease since it is a chronic disease and a treatment for life is necessary. The general objectives of the treatment are to get normoglycemia but also to take care of all the cardiovascular risk factors that are often associated with diabetes.

Fig. 4 Distribution of Patients by cholesterol value

Fig. 5 Distribution of patients populations by ASL/ASP values

But a second alternative is followed by diabetics: herbal medicine. In the Tlemcen region, the ethnobotanical information collected by Azzi et al., In 2012 [7], confirms the significant dependence of the local population on medicinal plants to treat diabetes. More than 80 species of medicinal plants have been listed in this region and are used alone or in combination with synthetic drugs.

Our study was conducted through a questionnaire made available to treating physicians. We have been able to recruit 100 cases of type 2 diabetics who are following the treatment prescribed by the doctors, metformin. These diabetics have been divided into three populations: the population 1 that does not consume medicinal plants, the population 2 that uses medicinal plants and the population 3 refer to non-diabetic control patients.

In terms of gender, our results show that diabetes affects both sexes with very different percentages. It is more common in women than in men. Our results are consistent with the work of Ouhdouch et al. (2008) [19] and Cicoletta et al. (2012) [20] who showed that the frequency of diabetes is not similar in both sexes with a female predominance. These figures vary by country and region of the world. The women predominance can be explained by the strict tendency of women to consult to be followed. This can be due to the

hormonal upheavals that are characteristic of menopause and the weight gain in the post-menopausal period. Women have a strong interest in acting on what they can master to reduce this risk [21]. Population 2 is divided into 24% men and 76% women, a sex ratio of 0.31. This predominance is also noticed in the consumption of medicinal plants. Most of the medicinal plant users in our study are female (76%), which was significantly associated with female sex ($p < 0.05$) [3]. According to the same author, this can be explained by the relative frequency of illiteracy of women, their vigilance for the balance of the disease, the ease of transmission of this information between them, the lower cost, and the attachment more great women at all that is traditional.

With regard to blood glucose, in our study, we obtained a very low glycemic level compared to that found in patients other studies. The values found in the two populations remain slightly higher compared to non-diabetic controls and fall within the range of blood glucose values of diabetic subjects. In studies by Rahmoun et al., (2019) [20] and UKPDS, (1994) [22], mean glycemic levels 214 and 206 mg/dL respectively were found. In our case, 84% of patients using herbs had a blood glucose level above 110 mg/dL while 81.8% of diabetics using the prescribed treatment had a normal blood glucose level. We also found that the population who consumes

Fig. 6 Distribution of population 2 according to the used plants

Table 2 Correlation matrix between the different biochemical parameters of the two studied populations (R^2 and p value)

	Pop1 fasting glucose	Pop2	Pop1 creatinine	Pop2	Pop1 ASP	Pop2	Pop1 TG	Pop2	Pop1 HbA _{1c}	Pop2
Creatinine	0.240	0.274								
p	0.283	≤ 0.05								
ASP	−0.147	−0.273	0.004	−0.150						
p	0.514	≤ 0.05	0.979	0.505						
TG	0.435	−0.040	−0.010	0.383	0.30	0.071				
p	≤ 0.05	0.781	0.943	0.079	0.838	0.752				
HbA _{1c}	0.385	0.693	0.232	0.013	−0.347	−0.181	0.051	0.106		
p	0.077	≤ 0.05	0.105	0.954	≤ 0.05	0.421	0.723	0.639		
Cholesterol	0.335	−0.260	−0.247	0.261	0.005	−0.110	0.214	0.308	−0.086	0.010
p	0.128	0.068	0.084	0.241	0.971	0.625	0.135	0.164	0.552	0.965

herbal medicine had a slightly high HbA_{1c}. Selihi et al., (2015) [6] showed that the use of plants to manage diabetes significantly associated with glycemic imbalance ($p < 0.05$).

The most consumers of plant in our population are female. These results are consistent with the work of Telli, (2016) [23] who obtained a frequency of 61% in the region of Ouargla in Algeria. Ouhdouch en (2008) [18] also achieved almost similar results in Marrakech with a frequency of plants uses of 64%. The percentages vary from one region to another. According to Eddouks (2002) [24], 80% of the patients questioned in Morocco are treated with medicinal plants. In 2011, 35% of French people recognized the use of herbal medicine in addition to conventional medicine. This is far from the results that we have obtained.

Most of the diabetic patients think to herbal medicine because medicinal plants are more accessible and easier to get than medical treatment. They prefer self-medication by plants instead of consulting a specialist. Medicinal plants are also more natural and relatively less expensive than prescription drugs. According to Selihi et al. (2015) [6] the main reasons for the use of herbal medicine are the low cost of plants (1.8% of patients), easy access to treatment (8.8%) and especially, the belief in the effectiveness of medicinal plants (89.5%). According to Noémie, (2017), herbal medicine in type 2 diabetes is mainly used to help lose weight, regulate blood sugar or limit the occurrence of complications associated with diabetes [25].

Thyme and olive and the peach were the most consumed plants in our study. This result is in agreement with a study carried out in Algeria by Telli, (2016) [23] where the most recorded plants were thyme with 81 citations and the olive tree with 82 citations. Another study done in Morocco by Eddouks, (2002) showed that the most recorded plant was the olive tree with 156 citations.

According to some studies, the enrichment of the diet with medicinal plants rich in polyphenols does not affect the glycemia of diabetic patients [7]. According to Solanki (2018) [26], the use of plants and phytoconstituants show beneficial

effects in the neuroprotection of diabetics. And even in the case of neuropathy and neurodegeneration, the plants tested in this study revealed a positive result in the treatment of this complication. These plants are *Angelica sinensis*, *Eugenia jambolana*, *Tinospora cordifolia*, *Vitis vinifera*, *Zingiber officinale*, *Ficus racemosa* and *Operculina turpethum*.

However, in the study of Noémie, (2017) [25], according to a clinical study, 11 plants have been reported to be hypoglycemic vegetable drugs in this case Garlic, Oat, Fenugreek, Fucus, Guar, Bean, Ispaghul, Konjac, Linen, Apple and Psyllium. These plants showed an ability to decrease the absorption of glucose and the mechanism of action was largely influenced by their high dietary fiber. Four of them have been selected as herbal drugs and herbal products with a favorable risk/benefit ratio: Garlic, Ispaghul, Konjac and Psyllium. Moreover, the search for a cheap treatment sometimes leads diabetics to use any plant. Some are too dangerous for antidiabetic use others can be antidiabetic but at doses that make them toxic.

But, according to Weidner et al., [10], the ethanolic lemon balm extract can potentially be used to prevent or concomitantly treat T2D and associated disorders such as dyslipidemia and hypercholesterolemia. Another study showed that the consumption of *M. officinalis* leaf powder as an adjunctive treatment in hyperlipidemic patients for 2 months lead to lower levels of LDL and AST. Moreover, the phenolic compounds of this herb could be considered as antihyperlipidemic agents of *M. officinalis* [11].

The use of plants is not without danger. In the study of Khatun et al. (2011) [27], a significant reduction in the absorption of metformin after consumption of certain plant extracts by diabetic patients has been demonstrated [28]. These plants have reduced the permeability of metformin in the intestinal tract and also affect metabolism in the liver and cause severe hypoglycaemia [6].

The mode of extraction of plants strongly influences the chemical composition of the extracts consumed. These

extracts are essentially in their raw state, which explains the high risk of microbial contamination (to bacteria and especially to fungi). In addition, in the case of misuse or recourse to the wrong choices of the plant, the undesirable effects can worsen and become complicated by simple diarrhea, itching, or palpitation, until serious general disorders able to leave significant sequelae or even death [28]. Abdel-Aal et al., (2008) [29] and Goldman et al., (2008) [30] demonstrated that consumption of medicinal plants may increase the risk of developing complications due to comorbidity or polypharmacy.

Plants should be used with vigilance and in combination with antidiabetic treatments, respecting any interactions, of interest in the management of type 2 diabetes and without toxicity. This last parameter is not to neglect although we did not note any values out of standard in the parameters hepatic (ASL and ASP) and renal (Urea and creatinine) of the diabetics studied. Rather, we found that plant consumption had an effect on the type of correlation between the biochemical parameters of diabetic patients. Positive and significant correlation of blood glucose with total cholesterol was found in the study of Rahmoun et al., (2019) [21]. The results found also revealed a low correlation of blood glucose with triglyceride levels or even a negative correlation with cholesterol. Chronic hyperglycemia is involved in the deregulation of lipid metabolism, which can be explained by the high risk of developing cardiovascular disease in type 2 diabetics.

Conclusion

It appears that herbal medicine remains a practice still widely used by the Algerian population for the treatment of diabetes, knowing that the latter is a frequent and serious metabolic disease threatening public health in the world, because of its heavy morbid consequences and its evolutionary character.

In our study population, the consumption of medicinal plants did not have a significant direct effect on the values of the measured biochemical parameters, but the correlation between these parameters was modified. The search for cheap treatment sometimes causes patients with diabetes to use just about any plant, some of which may have antidiabetic action, but at doses that make them toxic and too dangerous for therapeutic use, while others may cause the occurrence of one or more complications. Further efforts should be made to carry out more in-depth clinical research, as well as to sensitize the population, particularly diabetics and their families, about the dangers of uncontrolled use or concomitant plant medications, especially those with potential for toxicity, and their usual inefficiency.

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Compliance with ethical standards

Disclosure of interest The authors declare that they have no conflicts of interest concerning this article.

References

1. Tabish SA. Is diabetes becoming the biggest epidemic of the twenty-first century? *Int J Health Sci (Qassim)*. 2007;1(2):V–VIII.
2. Zhang P, Zhang X, Brown J, Vistisen D, Sicree R, Shaw J, et al. Global health care expenditure on diabetes for 2010 and 2030. *Diabetes Res Clin Pract*. 2010;87:293–301.
3. Mohammadi J, Saadipour K, Delaviz H, Mohammadi A. Anti-diabetic effects of an alcoholic extract of *Juglans regia* in an animal model. *Turk J Med Sci*. 2011;41(4):685–91.
4. Anoja PA, Kamani APW, Lakmini KBM. Study of antihyperglycaemic activity of medicinal plant extracts in alloxan induced diabetic rats. *Anc Sci Life*. 2013;32:193–8.
5. Al-Attar AM, Alsalmi FA. Effect of *Olea europaea* leaves extract on streptozotocin induced diabetes in male albino rats. *Saudi J Biol Sci*. 2019;26(1):118–28.
6. Selihi Z, Berraho M, El Achhab Y, Nejari C, Lyoussi B. Herbal medicine and degenerative complications of type 2 diabetes: what relationship? *Médecine des maladies Métaboliques*. 2015;9(8):792–7.
7. Muller M, Kersten S. Nutrigenomics: goals and strategies. *Nat Rev Genet*. 2003;4:315–22.
8. Akhoundan M, Shadman Z, Jandaghi P, Aboerad M, Larijani B, Jamshidi Z, et al. The association of bread and rice with metabolic factors in type 2 diabetic patients. *Plos One*. 2016;11(12):e0167921.
9. Almalki DA, Alghamdi SA, Al-Attar AM. Comparative study on the influence of some medicinal plants on diabetes induced by streptozotocin in male rats. *Biomed Res Int*. 2019;3596287.
10. Weidner C, Wowro SJ, Freiwald A, Kodelja V, Abdel-Aziz H, Kelber O, et al. Lemon balm extract causes potent antihyperglycemic and antihyperlipidemic effects in insulin-resistant obese mice. *Mol Nutr Food Res*. 2014;58:903–7.
11. Jandaghi P, Noroozi M, Ardalani H, Alipour M. Lemon balm: a promising herbal therapy for patients with borderline hyperlipidemia—a randomized double-blind placebo-controlled clinical trial. *Complement Ther Med*. 2016;26:136–40.
12. Ardalani H, Moghadam MH, Rahimi R, Soltani J, Mozayanimonfared A, Moradi M, et al. Sumac as a novel adjunctive treatment in hypertension: a randomized, double-blind, placebo-controlled clinical trial. *RSC Adv*. 2016;6(14):11507.
13. Barek S, Rahmoun NM, Aissaoui M, El Hachi IA, Bensouici C, Choukchou-Braham N. Phenolic contents, antioxidant, and antibacterial activities of the Algerian *Genista saharae* solvent extracts. *J Herbs Spices Med Plants*. 2019. <https://doi.org/10.1080/10496475.2019.1661327>.
14. Azzi R, Djaziri R, Lahfa F, Sekkal FZ, Benmehdi H, Belkacem N. Ethnopharmacological survey of medicinal plants used in the traditional treatment of diabetes mellitus in the North Western and South Western Algeria. *J Med Plants Res*. 2012;6:2041–50.
15. Ksira H, Sfar H, Hamdi S, Ben AN, Fendi O, Zarrouk M, et al. Utilisation des plantes hypoglycémiantes dans le traitement du diabète. *Ann Endocrinol*. 2014;75(5):385–6.
16. Cohen J. Statistical power analysis for the behavioral sciences. 2nd ed. Hillsdale: Erlbaum; 1988. p 79
17. World Health Organization, Global report on diabetes, World Health Organization, 2016, <http://www.who.int/iris/handle/10665/204871>.

18. Rahmoun MN, Ghembaza A, Habi MA. Glycated hemoglobin assay in a Tlemcen population: retrospective study. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*. 2018;12(6): 911–6.
19. Ouhdouch F, Errajaji A, Diouri A. La phytothérapie dans le traitement du diabète type 2. *Diabetes Metab*. 2008;34:40–100.
20. Cicolella A, Nalbone G, Cabon SL. Evaluation du lien entre curcumine pour prévenir le diabète de type 2. *Minerva*. 2012;12(2):19.
21. Rahmoun MN, Ghembaza CE, Ghembaza MA. Lipid profile in type 2 patients with diabetes from Tlemcen: a Western Algerian population. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*. 2019;13(2):1347–51.
22. UK Prospective Diabetes Study Group., UKPDS XII: Differences between Asian, Afro-Caribbean and White Caucasian type 2 diabetic patients at diagnosis of diabetes. UK Prospective Diabetes Study Group. *Diabet Med*. 1994;11(7):670–7.
23. Telli A, Esnault MA, El Hadj A, Khelil O. An ethnopharmacological survey of plants used in traditional diabetes treatment in South-Eastern Algeria (Ouargla province). *J Arid Environ*. 2016;127:82–92.
24. Eddouks M, Maghrani M, Lemhadri A, Ouahidi ML, Jouad H. Ethnopharmacological survey of medicinal plants used for the treatment of diabetes mellitus, hypertension and cardiac diseases in the south-east region of Morocco (Tafilalet). *J Ethnopharmacol*. 2002;82:97–103.
25. Noémie T. Diabète de type II : place de la phytothérapie dans le traitement et la prévention des complications. Thèse de doctorat en pharmacie. Université d'Angers. 2017; P12.
26. Solanki ND, Bhavsar SK, Pandya DT. Role of phytotherapy in diabetic neuropathy and neurodegeneration: from pathogenesis to treatment. *J Phytopharmacol*. 2018;2:152–61.
27. Khatun H, Rahman A, Biswas M, Islam AU. Water-soluble fraction of *Abelmoschus esculentus* L interacts with glucose and metformin hydrochloride and alters their absorption kinetics after coadministration in rats. *ISRN Pharm*. 2011;260537.
28. Millet Y, Jouglard J, Steinmetz MD, Tognetti P, Joanny P, Arditi J. Toxicity of some essential plant oils. Clinical and experimental study. *Clin Toxicol*. 1981;18:1485–98.
29. Abdel-Aal NM, Ahmad AT, Froelicher ES, Batieha AM, Hamza MM, Ajlouni KM. Prevalence of dyslipidemia in patients with type 2 diabetes in Jordan. *Saudi Med J*. 2008;29:1423–8.
30. Goldman RD, Rogovik AL, Lai D, Vohra S. Potential interactions of drug-natural health products and natural health products-natural health products among children. *J Pediatr*. 2008;152:521–6–526.e1–4.

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