International Journal of Food Sciences and Nutrition,
2011; Early Online: 1–8

informa
healthcare

Effect of Amla fruit (*Emblica officinalis* Gaertn.) on blood glucose and lipid profile of normal subjects and type 2 diabetic patients

MUHAMMAD SHOAIB AKHTAR[1], AYESHA RAMZAN[2], AMANAT ALI[3], & MAQSOOD AHMAD[1]

[1]*Department of Pharmacy, University of Sargodha, Sargodha, Pakistan,* [2]*Department of Home Economics, University of Agriculture, Faisalabad, Pakistan, and* [3]*Department of Food Science and Nutrition, College of Agricultural and Marine Sciences, Sultan Qaboos University, Al-Khoud, Muscat, Oman*

Abstract

The present study evaluated the anti-hyperglycemic and lipid-lowering properties of *Emblica officinalis* Gaertn. fruit in normal and diabetic human volunteers. The results indicated a significant decrease ($P < 0.05$) in fasting and 2-h post-prandial blood glucose levels on the 21st day in both normal and diabetic subjects receiving 1, 2 or 3 g *E. officinalis* powder per day as compared with their baseline values. Significant ($P < 0.05$) decreases were also observed in total cholesterol and triglycerides in both normal and diabetic volunteers on day 21 that were given either 2 or 3 g *E. officinalis* powder per day. However, diabetic volunteers receiving only 3 g *E. officinalis* powder exhibited a significant ($P < 0.05$) decrease in total lipids on day 21. Both normal and diabetic volunteers receiving 2 or 3 g *E. officinalis* powder significantly ($P < 0.05$) improved high-density lipoprotein-cholesterol and lowered low-density lipoprotein-cholesterol levels.

Keywords: Emblica officinalis *Gaertn., Amla fruit, blood glucose, lipid profile, normal and diabetic human volunteers*

Introduction

Although considerable progress has been made in the treatment and management of diabetes mellitus with conventional synthetic drugs (Davis 2007, Vinik 2007, Freeman 2010), there is still a continuous increase in its prevalence worldwide. The surge for the use of natural agents and alternative therapies in diabetes management is therefore now on the increase to lower the overall financial burden on public health services (Davis et al. 2009, Nampoothiri et al. 2010, O'Loughlin et al. 2010). In folk medicine, a large number of plants are allegedly used to treat diabetes mellitus (Said 1969, Sabu and Kuttan 2002, Rajagopal and Sasikala 2008, Kumar and Loganathan 2010, Sharma et al. 2010). Some of them have been reported to have the potential to significantly reduce the blood glucose levels when given either as a whole in powdered form or in the form of their aqueous or methanolic extracts (Akhtar 1992, Broadhurst et al. 2000, Khan et al. 2003, Rajagopal and Sasikala 2008). The data from the latest studies on indigenous medicinal plants have revealed the presence of many active principles that could prove useful for treating many diseases, including diabetes (Lewis and Elvin-Lewis 1977, Akhtar 1995, Hasani-Ranjbar et al. 2010). However, a substantial number of indigenous plants and herbs still await exploration by modern screening methods, especially in human patients.

Emblica officinalis Gaertn, commonly called Amla fruit or Indian Gooseberry, has traditionally been used for different medicinal purposes to treat the cerebral and intestinal ailments, diabetes mellitus, coronary heart diseases as well as cancers (Rajarama-Rao and Siddiqui 1964, Aslokar et al. 1992). *E. officinalis* Gaertn. has also been used to treat rheumatic pains, diseases of eye and genitalia, gonorrhea, constipation, asthma, biliousness and diarrhea, as well as a tonic for

Correspondence: Dr Amanat Ali, Department of Food Science and Nutrition, College of Agricultural and Marine Sciences, Sultan Qaboos University, P.O. Box 34, Al-Khod 123, Sultanate of Oman, Tel: 968 24141242. Fax: 968 24413418. E-mail: amanat@squ.edu.om

ISSN 0963-7486 print/ISSN 1465-3478 online
DOI: 10.3109/09637486.2011.560565

hair (Said 1969, Satyavati et al. 1976, Perry 1980). The leaves, fruit as well as its aqueous and methanolic extracts have shown hypoglycemic effects in animal models (Akhtar 1995, Sabu and Kuttan 2002). *E. officinalis* fruit and its extracts have shown anti-inflammatory, antioxidant and free radical scavenging properties in animal models (Asmawi et al. 1993, Hazra et al. 2010, Muthuraman et al. 2010, Nampoothiri et al. 2010, Reddy et al. 2010). *E. officinalis* has also been reported to have beneficial effects in the treatment of acute pancreatitis in rats (Sidhu et al. 2010). However, systematic scientific studies to clinically evaluate its anti-hyperglycemic and anti-hyperlipidemic effects in human volunteers are still limited. The present study was therefore conducted to evaluate the effects of powdered *E. officinalis* fruit on blood glucose levels and lipid profiles in normal subjects and type 2 diabetic human patients.

Materials and methods

Representative samples of *E. officinalis* Gaertn. fruit (commonly known as Amla) were obtained from local herbal market of Faisalabad (Pakistan). The fruits were washed with tap water, dried under shade, and powdered in a metallic pestle and mortar. The powdered samples were packed and sealed in cellophane bags and stored at 4°C.

A total of 32 volunteers (16 diabetic patients and 16 age-matched and gender-matched normal subjects) participated in the present study. The volunteers were of both sexes and their ages ranged from 30 to 60 years. The diabetic subjects were selected randomly from the outdoor clinics of University of Agriculture Faisalabad and Khadija Memorial Trust Hospital Faisalabad, Pakistan. All of the diabetic volunteers had been suffering from type 2 diabetes mellitus (i.e. non-insulin-dependent diabetes mellitus) for the past 5 years. They were found to be mostly on different oral hypoglycemic agents such as Daonil®, Glucophage®, Amaryl®, Novanol®, or herbal preparation, while the others were only using dietary management strategies. The history of each patient was recorded in a proper proforma and the diagnosis was confirmed with the proper laboratory tests. The diagnostic criteria used for the confirmation of diabetes mellitus was fasting plasma glucose level ≥ 7.0 mmol/l or 126 mg/dl or the 2-h plasma glucose level ≥ 11.1 mmol/l or 200 mg/dl (World Health Organization 2006). The age-matched and gender-matched normal subjects were selected either from the same family or from the similar socio-economic and cultural background. The normal subjects were apparently healthy and did not show any abnormal glucose tolerance test and lipid profile. The study was approved by the university ethics committee.

The volunteers were divided into two main groups (normal and diabetic). Each main group was then further randomly divided into four sub-groups with four volunteers in each. The normal human volunteers were divided into the four groups A, B, C and D comprising four volunteers in each group. Carboxymethyl cellulose fiber was given to group A that acted as control, while groups B, C and D were given 1, 2 or 3 g powdered *E. officinalis* fruit orally with 30 ml water once daily in the morning after breakfast. Similarly the diabetic patients were also divided into four groups (E, F, G and H), each comprising four volunteers. The diabetic volunteers in group E received glibenclamide orally (Daonil®) as a 5 mg tablet twice daily and acted as control. The diabetic human volunteers in groups F, G and H were given 1, 2 or 3 g powdered *E officinalis* fruit orally with 30 ml water once daily in the morning after breakfast. The fasting and 2-h postprandial (after breakfast) blood glucose levels were determined on 0 (baseline), 8, 15 and 21 days post treatment. The blood glucose levels of the volunteers were determined using glucose strips with the help of a Glucotrend glucometer (Roche, Milpitas, CA, USA). The blood glucose was determined at baseline (day 0) and on post-treatment days 8, 15 and 21 after the continuous daily oral intake of the powdered Amla fruit in the prescribed dosage. The fasting blood lipid profile was determined on 0 (baseline), 8, 15 and 21 days post treatment. The blood lipid profile parameters included total lipids, triglycerides, total cholesterol, high-density lipoprotein cholesterol (HDL-cholesterol) and low-density lipoprotein cholesterol (LDL-cholesterol). The blood lipid profile was determined with using the reagent kits from Randox Laboratories Limited (Crumlin, UK). Total lipids were determined with the help of a reagent kit method (Zoeliner and Kirsch 1962). Triglycerides were determined with the reagent kit method. Total cholesterol was determined with the reagent kit method (Richmond 1973). HDL-C was determined with the reagent kit method (Lopez-Virella 1977). LDL-C was calculated using the Friedewald Default (Friedewald et al. 1972). The data collected were subjected to statistical analysis using one-way analysis of variance, and the means were compared with least-significant-difference values and Duncan's multiple-range test as described by Steel et al. (1997).

Results

The average fasting blood glucose values (mean $\pm$ standard error of the mean) in normal and diabetic human volunteers are presented in Table I. A significant ($P < 0.05$) decrease in fasting blood glucose level was observed on day 21 as compared with baseline values (day 0) in both normal and diabetic volunteers in all groups (B, C, D, F, G and H) that were orally given 1, 2 or 3 g powdered Amla fruit once daily after breakfast. Such a decrease was, however, observed only in diabetic human subjects (group E) on days 8, 15 and 21 who were orally given a glibenclamide 5 mg tablet twice daily. The average

Table I. Average fasting blood glucose values (mg/dl) in normal and diabetic volunteers at baseline and after daily oral treatment with three doses of powdered Amla fruit (*E. officinalis*) and glibenclamide

	Time interval			
Treatment group	0 days	8 days	15 days	21 days
Normal individuals				
A	86.7 ± 6.1	87.2 ± 6.7	86.2 ± 7.3	85.2 ± 4.8
B	92.3 ± 6.4	88.0 ± 4.7	82.5 ± 3.6	79.0 ± 3.6*
C	99.8 ± 3.3	89.3 ± 3.1	80.3 ± 3.1*	73.5 ± 2.2**
D	99.0 ± 3.5	81.5 ± 3.9*	77.0 ± 2.4**	70.0 ± 2.5**
Diabetic patients				
E	133.0 ± 16.1	96.5 ± 12*	91.2 ± 11**	81.2 ± 10**
F	139.8 ± 11.8	129.5 ± 11.5	100.3 ± 10.3*	90.0 ± 6.8*
G	133.3 ± 13.0	110.0 ± 3.9	96.3 ± 3.9*	88.0 ± 3.7**
H	138.5 ± 1.1	91.5 ± 10.6*	81.3 ± 8.2**	73.0 ± 6.7**

Mean ± standard error of the mean ($n = 16$). A, carboxymethyl cellulose-treated normal group; B, C, D, normal groups receiving orally 1, 2 or 3 g Amla, respectively; E, diabetic group treated with glibenclamide (Daonil®) 5 mg twice daily; F, G and H, diabetic groups receiving orally 1, 2 or 3 g Amla, respectively. Significantly decreased from day 0 at *5% and **1%, respectively. All other values are non-significant ($P > 0.05$) from control.

blood glucose values (2-h post-prandial after breakfast) in normal and diabetic human subjects are presented in Table II. A significant ($P < 0.05$) decrease in blood glucose level was observed on days 8, 15 and 21 in normal volunteers given either 2 or 3 g powdered Amla fruit as compared with baseline values (day 0). However, all of the diabetic patients (groups F, G and H) exhibited significantly ($P < 0.05$) lower blood glucose levels on days 8, 15 and 21 as compared with baseline values (day 0).

The results on the effects of intake of powdered *E. officinalis* fruit on the blood lipid profile in normal subjects and type 2 diabetic human patients are shown in Tables III–VII. A significant ($P < 0.05$) decrease in total cholesterol values was observed in normal volunteers (groups C and D) as well as in diabetic patients (groups G and H) on days 8, 15 and 21 after treatment with powdered Amla fruit (Table lII). Similarly a significant ($P < 0.05$) decrease in triglyceride levels in groups C and D was observed in normal volunteers and diabetic patients (G and H). However, the volunteers in groups D and H, who were given 3 g powdered Amla fruit showed a significant ($P < 0.05$) decrease in their blood triglycerides levels on the 8th day (Table IV). Similar results were observed for the blood total lipid values (Table V). Both the normal human volunteers (groups B, C and D) and the diabetic patients (groups F, G and H) showed significantly ($P < 0.05$) lower total lipids values on days 15 and 21 after treatment with powdered Amla fruit as compared with baseline values (day 0). Significantly ($P < 0.05$) higher HDL-cholesterol values were observed in diabetic human volunteers who were given either 1, 2 or 3 g powdered Amla fruit per day on days 15 and 21 as compared with baseline values (day 0). In normal subjects, however, such an increase was only observed on the 21st day with a 2 g per day dose and on days 15 and 21 with a 3 g per day dose (Table VI). The average levels of LDL-cholesterol in normal and diabetic human volunteers

Table II. Average 2-h postprandial blood glucose values (mg/dl) in normal and diabetic human volunteers after daily oral treatment with three doses of powdered Amla fruit (*E. officinalis*) and glibenclamide.

	Time interval			
Treatment group	0 days	8 days	15 days	21 days
Normal individuals				
A	128.5 ± 9.3	127.5 ± 10.7	126.0 ± 9.2	122.0 ± 9.3
B	127.0 ± 9.5	113.5 ± 7.7	109.5 ± 7.9*	108.0 ± 18.5*
C	129.8 ± 7.1	106.0 ± 4.1*	93.8 ± 3.0**	94.5 ± 2.5**
D	126.8 ± 6.9	106.5 ± 3.1*	92 ± 3.7**	90.8 ± 2.5**
Diabetic patients				
E	283.5 ± 20.6	130.7 ± 12**	107.5 ± 8.4**	100.7 ± 3.4**
F	289.0 ± 24.9	179.3 ± 20.4*	168.8 ± 16.5*	138.5 ± 14.8**
G	246.8 ± 21.7	134.5 ± 11.9*	130.8 ± 11.6**	129.8 ± 10.9**
H	286.5 ± 23.2	124.8 ± 17.3**	111.0 ± 11.4**	108.3 ± 8.5**

Mean ± standard error of the mean ($n = 16$). A, carboxymethyl cellulose-treated normal group; B, C, D, normal groups receiving orally 1, 2 or 3 g Amla, respectively; E, diabetic group treated with glibenclamide (Daonil®) 5 mg twice daily; F, G and H, diabetic groups receiving orally 1, 2 or 3 g Amla, respectively. Significantly decreased from day 0 at *5% and **1%, respectively. All other values are non-significant ($P > 0.05$) from control.

Table III. Average fasting total cholesterol values (mg/dl) in normal and diabetic human volunteers after oral treatment with three doses of powdered Amla fruit (*E. officinalis*) and glibenclamide.

	Time interval			
Treatment group	0 days	8 days	15 days	21 days
Normal individuals				
A	175.5 ± 7.1	173.8 ± 8.1	177.3 ± 4.2	179.8 ± 4.4
B	162.5 ± 2.5	128.8 ± 3.1	121.3 ± 3.7	114.0 ± 3.5
C	169.5 ± 7.5	122.5 ± 6.5⋆	118.5 ± 3.4⋆⋆	101.8 ± 2.9⋆⋆
D	167.0 ± 6.5	139.5 ± 3.7⋆	114.8 ± 2.9⋆⋆	108.0 ± 2.4⋆⋆
Diabetic patients				
E	213.5 ± 21.7	219.7 ± 12.8	210.7 ± 8.38	209.2 ± 5.9
F	214.5 ± 23.8	203.5 ± 18.2	184.3 ± 14.8⋆	177.8 ± 5.5⋆
G	224.8 ± 13.7	188.5 ± 12.6⋆	177.8 ± 11.6⋆⋆	163.0 ± 10.2⋆⋆
H	226.5 ± 20.7	213.0 ± 20.1⋆	203.8 ± 16.1⋆⋆	168.8 ± 10.9⋆⋆

Mean ± standard error of the mean ($n = 16$). A, carboxymethyl cellulose-treated normal group; B, C, D, normal groups receiving orally 1, 2 or 3 g Amla, respectively; E, diabetic group treated with glibenclamide (Daonil®) 5 mg twice daily; F, G and H, diabetic groups receiving orally 1, 2 or 3 g Amla, respectively. Significantly decreased from day 0 at ⋆5% and ⋆⋆1%, respectively. All other values are non-significant ($P > 0.05$) from control.

Table IV. Average fasting triglycerides values (mg/dl) of normal and diabetic human volunteers after oral treatment with three doses of powdered Amla (*E. officinalis*) fruit and glibenclamide.

	Time interval			
Treatment group	0 days	8 days	15 days	21 days
Normal individuals				
A	191.2 ± 57.03	191.0 ± 51.71	196.2 ± 56.00	191.0 ± 55.83
B	126.8 ± 18.2	115.3 ± 20.7	96.5 ± 18.5	106.0 ± 14.3
C	175.5 ± 38.3	121.8 ± 25.2⋆⋆	115.5 ± 19.4⋆	112.0 ± 15.4⋆
D	159.8 ± 19.1	138.8 ± 15.5⋆⋆	126.3 ± 10.7⋆	121.0 ± 13.2⋆
Diabetic patients				
E	216.2 ± 21.7	239.0 ± 18.7	223.2 ± 17.3	214.2 ± 11.6
F	288.8 ± 26.1	295.3 ± 17.2	269.3 ± 19.1⋆	272.8 ± 13.4⋆
G	280.0 ± 27.9	227.3 ± 26.6⋆⋆	197.0 ± 20.2⋆⋆	147.0 ± 15.7⋆⋆
H	282.8 ± 22.8	214.3 ± 20.6⋆⋆	181.3 ± 19.9⋆⋆	134.0 ± 15.0⋆⋆

Mean ± standard error of the mean ($n = 16$). A, carboxymethyl cellulose-treated normal group; B, C, D, normal groups receiving orally 1, 2 or 3 g Amla, respectively; E, diabetic group treated with glibenclamide (Daonil®) 5 mg twice daily; F, G and H, diabetic groups receiving orally 1, 2 or 3 g Amla, respectively. Significantly decreased from day 0 at ⋆5% and ⋆⋆1%, respectively. All other values are non-significant ($P > 0.05$) from control.

Table V. Average fasting total lipids levels (mg/dl) of normal and diabetic human volunteers after treatment with three doses of powdered Amla (*E. officinalis*) fruit and glibenclamide.

	Time interval			
Treatment group	0 days	8 days	15 days	21 days
Normal individuals				
A	527.2 ± 18.0	521.2 ± 19.4	525.5 ± 16.0	539.2 ± 14.9
B	487.5 ± 17.6	386.1 ± 13.3⋆	363.8 ± 13.2⋆	342.0 ± 12.4⋆
C	508.5 ± 27.3	427.5 ± 29.3⋆	415.5 ± 22.3⋆	395.3 ± 20.9⋆⋆
D	501.0 ± 20.6	418.5 ± 20.0⋆	404.3 ± 18.7⋆	384.0 ± 13.1⋆⋆
Diabetic patients				
E	640.5 ± 24.70	659.2 ± 29.86	641.2 ± 31.12	660.0 ± 37.3
F	643.5 ± 31.2	640.5 ± 24.6	582.8 ± 24.4⋆	563.3 ± 16.6⋆
G	554.3 ± 31.1	555.5 ± 30.9	523.3 ± 20.8⋆	519.0 ± 20.6⋆
H	649.5 ± 32.1	639.0 ± 36.2	511.3 ± 31.3⋆	506.3 ± 30.7⋆

Mean ± standard error of the mean ($n = 16$). A, carboxymethyl cellulose-treated normal group; B, C, D, normal groups receiving orally 1, 2 or 3 g Amla, respectively; E, diabetic group treated with glibenclamide (Daonil®) 5 mg twice daily; F, G and H, diabetic groups receiving orally 1, 2 or 3 g Amla, respectively. Significantly decreased from day 0 at ⋆5% and ⋆⋆1%, respectively. All other values are non-significant ($P > 0.05$) from control.

Table VI. Average fasting HDL-cholesterol values (mg/dl) of normal and diabetic human volunteers after treatment with three doses of powdered Amla (*E. officinalis*) fruit glibenclamide.

	Time interval			
Treatment group	0 days	8 days	15 days	21 days
Normal individuals				
A	65.8 ± 25.5	66.8 ± 2.7	66.0 ± 3.0	64.2 ± 2.9
B	37.0 ± 1.4	36.8 ± 1.2	37.5 ± 1.3	37.8 ± 1.4
C	39.5 ± 1.0	37.5 ± 0.8	37.5 ± 0.9	46.5 ± 1.2*
D	39.3 ± 1.4	36.5 ± 1.5	46.8 ± 0.9*	56.5 ± 0.5**
Diabetic patients				
E	47.5 ± 5.3	49.5 ± 4.7	48.2 ± 4.9	47.2 ± 5.4
F	46.8 ± 4.5	48.8 ± 4.2	48.8 ± 4.2*	50.3 ± 2.8*
G	48.3 ± 3.9	47.3 ± 2.6	63.0 ± 2.9*	69.3 ± 2.9*
H	49.8 ± 3.9	46.3 ± 5.9	59.8 ± 4.3*	83.3 ± 3.1*

Mean ± standard error of the mean ($n = 16$). A, carboxymethyl cellulose-treated normal group; B, C, D, normal groups receiving orally 1, 2 or 3 g Amla, respectively; E, diabetic group treated with glibenclamide (Daonil®) 5 mg twice daily; F, G and H, diabetic groups receiving orally 1, 2 or 3 g Amla, respectively. Significantly decreased from day 0 at *5% and **1%, respectively. All other values are non-significant ($P > 0.05$) from control.

Table VII. Average fasting LDL-cholesterol values (mg/dl) in normal and diabetic human volunteers after treatment with three doses of powder Amla fruit (*E. officinalis)* and glibenclamide.

	Time interval			
Treatment group	0 days	8 days	15 days	21 days
Normal individuals				
A	71.5 ± 4.2	68.8 ± 4.9	72.6 ± 7.5	77.4 ± 8.1
B	100.1 ± 2.2	68.9 ± 1.0*	64.5 ± 0.5*	54.5 ± 1.2*
C	94.9 ± 3.0	60.6 ± 7.3*	57.9 ± 5.5*	57.9 ± 7.4**
D	95.7 ± 6.6	75.2 ± 5.6*	42.7 ± 6.8*	47.7 ± 5.6**
Diabetic patients				
E	122.8 ± 18.3	122.4 ± 19.5	117.8 ± 11.1	119.2 ± 42.2
F	109.9 ± 18.9	95.6 ± 14.1	81.6 ± 11.4*	72.9 ± 8.8*
G	120.8 ± 6.6	95.7 ± 14.9	75.4 ± 3.9*	64.3 ± 3.2**
H	119.9 ± 8.4	124.1 ± 8.0	107.7 ± 6.4**	58.7 ± 2.4**

Mean ± standard error of the mean ($n = 16$). A, carboxymethyl cellulose-treated normal group; B, C, D, normal groups receiving orally 1, 2 or 3 g Amla, respectively; E, diabetic group treated with glibenclamide (Daonil®) 5 mg twice daily; F, G and H, diabetic groups receiving orally 1, 2 or 3 g Amla, respectively. Significantly decreased from day 0 at *5% and **1%, respectively. All other values are non-significant ($P > 0.05$) from control.

are presented in Table VII. The results reveal that LDL-cholesterol levels decreased significantly ($P < 0.05$) on days 8, 15 and 21 as compared with baseline values (day 0) in the normal volunteers (groups B, C and D). Whereas in diabetic patients a significant decrease in LDL-cholesterol values was only observed on days 15 and 21 as compared with the baseline values (day 0).

Discussion

The use of natural agents and alternative therapies in the treatment and management of diabetes mellitus is becoming increasingly popular not only to reduce the side effects of synthetic medicines but also to lower the overall financial burden caused by the disease (Morelli and Zoorob 2000, Davis et al. 2009, Nampoothiri et al. 2010, O'Loughlin et al. 2010). Many indigenous medicinal plants and herbs contain a number of active principles, which have shown anti-hyperglycemic, anti-hyperlipidemic and anti-inflammatory effects in animal models and could therefore be useful for treating many diseases including diabetes (Lewis and Elvin-Lewis 1977, Akhtar 1995, Rajagopal and Sasikala 2008, Hasani-Ranjbar et al. 2010, Kumar and Loganathan 2010). *E. officinalis* Gaertn., which is commonly called Amla fruit or Indian Gooseberry, has traditionally been used in folk medicine to prevent and treat many diseases such as rheumatic pains, diseases of the eye and genitalia, constipation, asthma, cerebral and intestinal ailments, diabetes mellitus, coronary heart diseases as well as cancers (Rajarama-Rao and Siddiqui 1964, Said 1969, Satyavati et al. 1976, Aslokar et al. 1992).

The results of the present study indicated a significant decrease ($P < 0.05$) in fasting and 2-h post-prandial blood glucose on day 21 in normal subjects and diabetic patients as compared with baseline values (day 0). The supplementation of powdered Amla fruit at all the given doses did not

show any negative impact on blood glucose levels in both the normal and diabetic subjects as these values remained within the normal blood glucose range; that is, 70–110 mg/dl (World Health Organization 2006). These results are in line with the previously reported data that showed different medicinal plants and herbs have the potential to significantly and consistently reduce the blood glucose levels in normal and alloxan-induced diabetic rats and rabbits (Akhtar 1982, 1992, Mossihuzzaman et al. 1994). C*uminum nigrum* (black cumin) seeds when given at different doses (1, 2, 3 or 4 g/kg body weight) produced a significant hypoglycemic effect in normal and alloxan-induced diabetic rabbits (Akhtar et al. 1981, Akhtar and Ali 1985, Mushtaq et al. 2000). Kumar and Loganathan (2010) suggested that *Spinacia oleraceae* possesses anti-diabetic principle and can be useful for the treatment of diabetes. *E. officinalis* has also been reported to be beneficial in the treatment of acute pancreatitis in rats (Sidhu et al. 2010). The potent antioxidant, anti-inflammatory and free radical scavenging activities of *E. officinalis* fruits extracts might play an important role for its beneficial effects in controlling the hyperglycemia and dyslipidemia and may reduce the risk of diabetes and other diseases (Hazra et al. 2010, Nampoothiri et al. 2010, Muthuraman et al. 2010, Reddy et al. 2010). Kim et al. (2010) suggested that polyphenol rich fractions of *E. officinalis* Gaertn. can attenuate the fructose-induced metabolic syndrome. The higher antioxidant activity of *E. officinalis* has also been attributed to its vitamin C content (Scartezzini et al. 2006).

Measurement of the serum lipid profile is considered one of the important screening procedures to find out the cardiac risk in population. A lipid profile is a direct measure of blood components such as total lipids, triglycerides total cholesterol, HDL-cholesterol and LDL-cholesterol. Factors such as age sex, genetic, diabetes and diet influence the lipid profile (Robert 2002). Significant ($P < 0.05$) decreases in total cholesterol and triglyceride levels were observed in both the normal and diabetic volunteers on day 21 who were given either 2 or 3 g herbal powder. The volunteers in the diabetic sub-group, who received 3 g herbal powder, exhibited a significant ($P < 0.05$) decrease in total lipids on day 21. Both the normal and diabetic volunteers in all the sub-groups receiving 2 or 3 g herbal powder showed a significant ($P < 0.05$) improvement in the LDL-cholesterol values on days 15 and 21 as compared with baseline values (day 0). Simultaneously a significant decrease in the LDL-cholesterol levels was observed. The data indicated that the intake of powdered *E. officinalis* fruit worked in a dose-dependent and time-dependent manner in reducing the blood glucose levels and lipid profile in normal subjects as well as type 2 diabetic human patients. Mand et al. (1991) observed a decrease in plasma lipids and cholesterol levels and an increase in lipid mobilization and catabolism in experimental hypercholesterolemic rabbits when they were given *E. officinalis* (Amla fruit powder) for 12 weeks. The fresh juice of *E. officinalis* when given to cholesterol-fed rabbits acted as an anti-hyperlipidemic agent. It has been suggested that *E. officinalis* can be used as a pharmaceutical tool to lower lipid profile in hyperlipidemic subjects (Mathur et al. 1996). *E. officinalis* Gaertn. (Amla fruit) contains high quantities of polyphenols, vitamin C and dietary fiber (Scartezzini et al. 2006, Muthuraman et al. 2010) that might have been effective in achieving the cholesterol lowering effects in both normal and diabetic subjects. Higher intakes of dietary fiber are associated with lowering of blood cholesterol and triglyceride levels in diabetic subjects (Pedersen et al. 1992, He et al. 1995, Vessby et al. 2000). Studies suggest that blood triglyceride levels >400 mg/dl could first be treated with non-pharmacologic approaches including weight loss, low-fat diet, avoidance of excess alcohol and regular aerobic exercise before the use of drugs (Lorgeril 1999). Diets low in saturated fat or very low in total fat contents are considered to be associated with lowering of low-density lipoprotein cholesterol (Grundy 1998). Under such conditions, the use of *E. officinalis* Gaertn. (Amla fruit) could be a good alternative therapy to treat the hyperlipidemia.

Obviously the oral anti-hyperglycemic agents from plants and herbs are of no great value in the treatment of any type of severe diabetes as β-cells (Islets of Langerhans) in diabetic patients have already been damaged to the extent that they might have lost all their potential to secrete insulin. The search for more effective and safer anti-diabetic agents is therefore continuing to be an area of active research. The present study in human subjects has confirmed the previous results already obtained in animal models. It is therefore conceivable that the hypoglycemic principles contained in the *E. officinalis* Gaertn. (Amla fruit) may act by stimulating the insulin release from the β-cells of the normal and type 2 diabetics. The Amla fruit, however, appears to contain more than one active principle (Muthuraman et al. 2010, Naampothiri et al. 2010, Reddy et al. 2010), which may act not only indirectly by initiating the release of insulin but may also have a direct insulin-like effect as shown in alloxan-induced diabetic animals, because their β-cells are unable to produce and release any insulin. The results of this study support the hypothesis that in mild and moderate type 2 diabetic patients, the oral administration of powdered Amla fruit would be sufficiently effective to control their blood glucose levels if given in appropriate doses. However, in severely diabetic patients the plant drug may have to be supplemented with small doses of any other oral anti-hyperglycemic drug such as sulphonylureas. It is possible that this cheap medicinal fruit may ultimately prove to be an extraordinarily valuable anti-diabetic agent since, in addition to its non-toxic insulin releasing and insulin-like activities, it can also

compensate for the mineral deficiencies that occur in diabetes due to osmotic diuresis (Laurence and Bacharach 1964, Garg et al. 2005). Virtually, *E. officinalis* Gaertn. (Amla fruit) is being used as a food and drug in traditional medicine for centuries and has already been reported to be safe for human use.

Conclusion

Overall, the results of the present study suggest that Amla fruit (*E. officinalis*, Gaertn.) has both anti-hyperglycemic and lipid-lowering properties and might be used as an ideal plant food supplement in developing successful alternative therapies in the prevention and treatment of diabetes, dyslipidemia, obesity and cancers in general population. However, further comprehensive phytochemical studies, followed by pharmacological evaluations in animal models and subsequently in humans, are required to evaluate and pinpoint the real hypoglycemic principle(s) and to precisely determine the mechanism(s) of its hypoglycemic actions.

Acknowledgements

The authors would like to thank the volunteers for their sincere cooperation towards the successful completion of the present study.

Declarations of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

Akhtar MS. 1982. Trials of *Momordica charantia* powder in patients with maturity onset diabetes: A preliminary report. J Pak Med Acad 32:106–107.

Akhtar MS. 1992. Hypoglycemic activities of some indigenous medicinal plants traditionally used as anti-diabetic drug. J Pak Med Acad 42:271–277.

Akhtar MS. 1995. Efficacy of some indigenous medicinal plants in diabetic patients. In: Proceedings of the 2nd Annual National Symposium on Health Care and Social Development. Karachi, Pakistan: The Aga Khan University. p 232–236.

Akhtar MS, Ali MR. 1985. Study of hypoglycemic activity of *Cuminum nigrum* seeds in normal and alloxan-diabetic rabbits. Planta Med 51:81–85.

Akhtar MS, Akhtar MA, Yaqub M. 1981. Effect of *Momordica charantia* on blood glucose level of normal and alloxan diabetic rabbits. Planta Med 42:205–212.

Aslokar L, Kakkar KK, Chakre OJ. 1992. Supplement to Glossary of Indian Medicinal Plants with Active Principles. New Delhi, India: Directorate of CSIR. p 291–293.

Asmawi MZ, Kankaanranta H, Moilanen R. 1993. Anti-inflammatory activities of *Emblica officinalis* Gaertn leaf extracts. J. Pharm Pharmacol 45:581–584.

Broadhurst CL, Polansky MM, Anderson RA. 2000. Insulin like biological activity of culinary and medicinal plant extracts in-vitro. J Agric Food Chem 48:849–852.

Davis SN. 2007. Management of type 2 diabetes mellitus with basal prandial insulin therapy: A case based review. Insulin 2: 118–126.

Davis N, Forbes B, Wylie-Rosett J. 2009. Nutritional strategies in type 2 diabetes. Mount Sinai J Med 76:257–268.

Freeman JS. 2010. New therapeutic options: Management strategies to optimize glycemic control. J Am Osteopath Assoc 110(3 Suppl 2):515–520.

Friedewald WT, Levy RI, Fredrickson DS. 1972. Estimation of the concentration of low density lipoprotein cholesterol in plasma, without use of preparative ultracentrifuge. Clin Chem 18: 499–502.

Garg AN, Kumar A, Nair AG, Reddy AVR. 2005. Determination of minor and trace elements in *Trifla*—A herbal preparation. J Radioanal Nucl Chem 263:751–758.

Grundy SM. 1998. Dietary influence on serum lipids and cholesterol. J lipids Res 31:1149–1172.

Hassani-Ranjbar S, Nayebi N, Moradi L, Mehri A, Larijani B, Abdollahi M. 2010. The efficacy and safety of herbal medicines used in the treatment of hyperlipidemia: A systematic review. Curr Pharmac Design 16:2935–2947.

Hazra B, Sarkar R, Biswas S, Mandal N. 2010. Comparative study of anti-oxidant and reactive oxygen speciesscavenging properties in the extracts of fruits of *Terminalia chebula*. *Terminalia belerica* and *Emblica officinalis*. BMC Complementary Alternative Med 10: 20.

He J, Klag MJ, Whelton PK, Mo JP, Chen JY, Qian MC, Mo PS, He GQ. 1995. Oat bran intake selectively lower serum LDL-C concentration of hypercholesterolemic men. Am J Clin Nutr 61: 366–372.

Khan A, Safdar M, Khan MMA, Khattak KN, Anderson AR. 2003. Cinnamon improves glucose and lipids of people with type 2 diabetes. Diabetes Care 26:3215–3218.

Kim HY, Okubo T, Juneja LJ, Yokozawa T. 2010. The protective role of Amla (*Emblica officinalis* Gaertn) against fructose-induced metabolic syndrome in a rat model. Br J Nutr 103:502–512.

Kumar NJ, Loganathan P. 2010. Hypoglycemic effects of *Spinacia oleracea* in alloxan induced diabetic rats. Global J Biotech Biochem 5:87–91.

Laurence DR, Bacharach AL. 1964. Evaluation of Drug Activities: Pharmacometrics. London: Academic Press. p 33–35.

Lewis HW, Elvin-Lewis MPH. 1977. Medical Botany: Plant Affecting Man's Health. New York: John Wiley and Sons : 217–218.

Lopez-Virella MF. 1977. High density lipoprotein cholesterol estimation. Clin Chem 23:882–884.

Lorgeril W. 1999. The medical consequences of high level of triglycerides. Exp Clin Endocrinol Diabetes 106:1–6.

Mand JK, Soni GL, Gupta PP, Singh R. 1991. Effect of Amla (*Emblica officinalis*) on the development of atherosclerosis on hypercholesteromic rabbits. Punjab Agric Univ Ludhiana J Res Edu 10(2):1–7.

Mathur R, Sharma A, Dixit VP, Varma M. 1996. Hypolipidemia effect of fruit juice of *Embilica officinalis* in cholestrol-fed rabbits. J Ethnopharmacol 50(2):61–68.

Morelli V, Zoorob RJ. 2000. Alternative therapies Part I. Depression, diabetes, obesity. Ann Farm Physician 62: 1051–1060.

Mossihuzzaman M, Nahar N, Ali L. 1994. Hypoglycaemic effects of three plants form Eastern Himalayan belt. Diabetes Res 26(3): 127–138.

Mushtaq A, Almas K, Hashmi AS, Hussain SJ, Ahmad I. 2000. Alloxan induced diabetic rabbits. Effects of fibrous and non-fibrous diets on serum glucose and some lipid profile. Prof Med J 7(3):309–312.

Muthuraman A, Sood S, Singla SK. 2010. The anti-inflammatory potential of phenolic compounds from *Emblica officinalis* L. in rats. Inflammopharmacology. Published online on 2nd July 2010. DOI 10.1007/s 10787-010-0041-9.

Nampoothiri SV, Prathapan A, Cherian OL, Raghu KG, Venugopalan VV, Sunderasan A. 2010. In-vitro antioxidant and inhibitory potential of *Terminalia bellerica* and *Emblica officinalis*

fruits against LDL oxidation and key enzymes linked to type 2 diabetes. Food Chem Toxicol 49:125–130.

O'Loughlin A, McIntosh C, Dinneen SF, O'Brien T. 2010. Basic concepts to novel therapies: A review of the diabetic foot. Int J Lower Extremity Wounds 9:90–102.

Pederson O, Hermenson K, Palmvig B, Pederson SE, Sondergaard K. 1992. Dietary treatment of diabetes recommendations in 1990's. Ugesker Lal ger 154(14):910–916.

Perry LM. 1980. Medicinal Plants of East and South-East Asia: Attributed Properties and Uses. Cambridge, MA: MIT Press. p 149–150.

Rajagopal K, Sasikala K. 2008. Antihyperglycaemic and antihyperlipidemic effects of *Nymphaea stellata* in alloxan-induced diabetic rats. Singapore Med J 49(2):137–141.

Rajarama-Rao MR, Siddiqui HH. 1964. Pharmacological studies on *Emblica officinalis* Gaertn. Indian Exp Biol 2:29–31.

Reddy VD, Padmavathi P, Kavitha G, Gopi S, Varadacharyulu N. 2010. *Emblica officinalis* ameliorates alcohol-induced brain mitochondrial dysfunction in rats. J Med Foods 14:62–68.

Richmond W. 1973. Preparation and properties of a cholesterol oxidase from *Nocardia* sp. and its application to the enzymatic assay of total cholesterol in serum. Clin Chem 19:1350–1356.

Robert S. 2002. Diabetes Self-management. New York: R.A. Rappaport Publishing Company.

Sabu MC, Kuttan R. 2002. Anti-diabetic activities of medicinal plants and its relationship with their antioxidant properties. J Ethnopharmacol 81:155–160.

Said M. 1969. Hamdard Pharmacopoeia of Eastern Medicine. Sadar Karachi, Pakistan: Time Press. p 379.

Satyavati GV, Raina MK, Sharma M. 1976. Medicinal Plants of India. Vol. 1. New Delhi: Indian Council of Medical Research. p 48–51.

Scartezzini P, Antognoni F, Raggi MA, Poli F, Sabbioni C. 2006. Vitamin C content and antioxidant activity of the fruit and of the Ayurvedic prepration of Emblica officinalis Gaertn. J Ethnopharmacol 104:113–118.

Sharma VK, Kumar S, Patel HJ, Hugar S. 2010. Hypoglycemic activity of *Ficus glomerata* in alloxan-induced diabetic rats. Int J Pharmac Sci Res 1(2):18–22.

Sidhu S, Pandhi P, Malhotra S, Vaiphei K, Khanduja KL. 2010. Beneficial effects of *Emblica officinalis* in L-arginine induced acute pancreatitis in rats. J Med Food 14:147–155.

Steel RGD, Torrie JH, Dickey DA. 1997. Principles and Procedures of Statistics. A Biometrical Approach. 3rd ed. New York: McGraw Hill Publishing Company.

Vessby B, Karlstron B, Ohroal M, Jarvi A, Anderson A, Basil S. 2000. Diet, nutrition and diabetes mellitus. UPS J Med Sci 105: 151–160.

Vinik A. 2007. Advancing therapy in type 2 diabetes mellitus with early comprehensive progression from oral agents to insulin therapy. Clin Ther 29:1236–1253.

World Health Organization. 2006. Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycemia: Report of a World Health Oranization (WHO) and International Diabetes Federation (IDF) Consultation. Geneva, Switzerland: WHO Document Publication Services.

Zoeliner N, Kirsch K. 1962. Uber die quantitative Bestimmung von lipiden (mikromethode) mittels der vielen naturlischen lipiden (alle bekannten plasma lipiden) gemeinsamen sulfophosphovanillin reaktion. Z Gesamte Exp Med 135:545–561.