

Research Article

Malus domestica as an Inhibitor of Glycation

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Abstract: Diabetes mellitus is a metabolic disorder that is principally characterized by insulin resistance, relative insulin deficiency and hyperglycemia. The present research work was designed to study the inhibition of glycation with natural Inhibitor "*Malus domestica*". For this purpose, normal plasma was collected from healthy volunteers. To study glycation inhibition, thirty two combinations were made and all these combinations were placed at 37°C at same time for five weeks. Human normal plasma was used as a protein. Four milliliter of samples was drawn after 1st, 2nd, 3rd, 4th and 5th week of incubation to perform the experiments. Browning production was recorded by taking absorbance at 370nm of all combinations. Dialysis was performed to remove the excess/ free glucose. Glucose and protein estimation was done to check the glucose and protein concentration before and after dialysis. Glycation inhibition was measured with TBA assay and also by ELISA. The activity of I₂ (10 times diluted) inhibitor was approximately high mainly in the 2nd week of incubation. "*Malus domestica*" is effective and efficient in lowering the glycation level in conditions when the level of glucose is high i.e. in diabetes. So the results indicate that in future "*Malus domestica*" can be used for lowering glucose level in the body.

Keywords: Advanced Glycation end products, Non-Insulin Dependant Diabetes Mellitus, Inhibitor, Enzyme linked Immunosorbent Assay, ThiobarbituricAcid.

INTRODUCTION

Glycation is a haphazard process that impairs the functioning of biomolecules, Glycation (sometimes called non-enzymatic glycosylation) is the result of a sugar molecule, such as fructose or glucose, bonding to a protein or lipid molecule without the controlling action of an enzyme [1]. It has been known for a long time that human blood proteins like hemoglobin [2] and serum albumin [3, 4] may undergo a slow non-enzymatic glycation, mainly by formation of a Schiff base between gamma amino groups of lysine (and sometime arginine) residues and glucose molecules in blood (Milliard reaction). This reaction can be inhibited in the presence of antioxidant agents [5] although this reaction may happen normally elevated glycoalbumin is observed in diabetes mellitus [4].

Advanced glycation End products (AGEs) are formed as a result of a chain of chemical reactions after an initial glycation reaction [6-8]. AGEs may be formed external to the body (exogenously) by heating (e.g., cooking) sugars with fats or proteins [9] or inside the body (endogenously) through normal metabolism and aging [10].

The genesis of free radicals in diabetes include autoxidation processes of glucose, the non-enzymatic and progressive glycation of proteins with the consequently increased formation of glucose-derived advanced glycosylation end products (AGEs)[11], and enhanced glucose flux through the polyol pathway [12].

Elevated generation of free radicals resulting in the consumption of antioxidant defense components may lead to disruption of cellular functions and oxidative damage to membranes and may enhance susceptibility to lipid peroxidation [13]. Under physiological conditions, a widespread antioxidant defense system protects the body against the adverse effects of free radical production [14]. The antioxidant defense system represents a complex network with interactions, synergy and specific tasks for a given antioxidant [15]. The efficiency of this defense mechanism is altered in diabetes and, therefore, the ineffective scavenging of free radicals may play a crucial role in determining tissue damage [16].

Recent decades have shown a rising interest in traditional plant treatments for diabetes. Plants often contain substantial amounts of antioxidants including tocopherol (vitamin E), carotenoids, ascorbic acid (vitamin C), flavonoids and tannins [17] and it has been suggested that antioxidant action may be an important property of plant medicines used in diabetes

The apple is the pomaceous fruit of the apple tree, species *Malus domestica* in the rose family (Rosaceae). It is one of the most widely cultivated tree fruits, and the most widely known of the many members of genus *Malus* that are used by humans [18]. Apple is one of the few medicinal plants that has maintained its popularity for a long period of time. They help with diabetes, heart disease, weight loss, and

controlling cholesterol. The fiber contained in apples reduces cholesterol by preventing reabsorption [19]. Laboratory studies have also found that components in apple have anticancer activity [20]. Clinical evaluations have revealed that the pharmacologically active ingredients are concentrated in both the extract. Most experimental results were highly encouraging as they revealed that level of blood glucose was significantly lower after oral administration of ethanolic extract of apple in glucose load condition and in STZ-induced diabetes [21].

Apple treatment showed 49% decrease in blood sugar levels and a 52% decrease in triglycerides at day 42 and no change in cholesterol on using along with glibenclamide [22]. Oral administration of processed "*Malus domestica*" prevented the progression of NIDDM-related symptoms in high-fat diet-fed mice, and suggested that PAG could be useful for treating NIDDM [23]. Use of "*Malus domestica*" is being promoted for a large variety of conditions. Oral administration of "*Malus domestica*" might be a useful adjunct for lowering blood glucose in diabetic patients as well as for reducing blood lipid levels in patients with hyperlipidaemia [24]. "*Malus domestica*" extract showed hyperglycaemic activity on NIDDM rats [25]. The ethanolic extract of "*Malus domestica*" appeared to be more effective than glibenclamide in controlling oxidative stress [26].

The present project was designed to study the effect of aqueous extract of *Malus domestica* on production of advanced glycation end products (AGEs). For this purpose the most active concentration of glucose was optimized and investigated. The most active concentration of inhibitor was also optimized and investigated.

MATERIALS AND METHODS

To study the effect of Apple (*Malus domestica*) on the formation of advanced glycation end product *in-vitro* thirty-two combinations (Table 1) were made and all these combinations were placed at 37°C for five weeks. Plasma was used as a protein sample. 0.1 milliliter of samples was drawn after 1st, 2nd, 3rd, 4th and 5th weeks of incubation to perform the experiments for advanced glycation end product inhibition. At temperature (37°C) different concentrations of glucose and inhibitor were used. Dilution of plasma and solution of glucose and inhibitor were made in phosphate saline buffer (PBS). (75Mm, pH: 7.4 containing Sodium azide).

In-vitro Inhibition

In-vitro glycation of plasma (Preparation of Plasma- AGE): Plasma was incubated with all glucose concentrations with and without inhibitor in phosphate buffer saline (containing Sod. azide) at 37°C for 1-5 weeks simultaneously [27].

In-vitro Inhibition with Plasma

Three different concentrations of inhibitors were incubated with plasma (10mL) and 3 different concentration of glucose for detecting advanced glycation end product inhibition.

Glucose Concentrations

Glucose 1: 50mmol, Glucose 2: 25mmol, Glucose 3: 5.5mmol

Inhibitor Apple (*Malus domestica*) Concentrations

Inhibitor 1=I₁= Extract (as such), Inhibitor 2=I₂=10 times diluted, Inhibitor 3=I₃= 20 times diluted

Protein (Plasma) Concentrations: Protein: 25mg/ml

Samples were drawn after 1st, 2nd, 3rd, 4th and 5th weeks of incubation to perform the experiments for advanced glycation end product inhibition. In above each week 0.1ml sample was taken from original and remaining again placed at 37°C. Then added 3.9ml distilled water in it and made volume 4ml. Then absorbance was taken at 370nm. Sample blanks will be run with each condition of glucose and inhibitor concentration. Later on samples were dialyzed to get rid of free glucose [28] by using dialyzing membrane.

Total proteins in all samples after dialysis were determined by Biuret method using biuret reagent [29]. Measuring protein before and after dialysis monitored sensitivity and validity of method. Glycation (enzymatic and non-enzymatic) was estimated by TBA technique [30] taking absorbance at 370nm using spectrophotometer. Advanced Glycation End Product (AGEs) was determined by using ELISA following the procedure of Zhang *et al.* [31], using alkaline phosphatase enzyme and paranitrophenyl phosphate as a substrate. Data will be analyzed according to statistical methods like means, standard error of mean and regression techniques [32].

RESULTS AND DISCUSSION

Browning Production Determination at different concentrations of glucose with inhibitor at 37°C in plasma. Our results indicated that in case of plasma incubated with glucose concentration of G₁ (50mM) showed maximum absorbance (fluorescence) (1.99) at 2nd week of incubation and minimum absorbance at 4th week (0.271). I₁ showed minimum absorbance (fluorescence) at 3rd week (0.217) as compared to I₂ and I₃ at 37 °C (Fig.1). It indicated that suitable amount of inhibitor (I₁) most effectively decreased browning in 3rd week as compared to other combinations.

In case of plasma incubated with glucose concentration of G₂ (25mM) showed maximum absorbance (fluorescence) (0.938) at 1st week of incubation and minimum absorbance at 3rd week (0.196). I₁ showed minimum absorbance (fluorescence) in 2nd week (0.128) as compared to I₂ and I₃ at 37 °C in

hot extract (Fig. 2). It indicated that suitable amount of hot inhibitor (I₁) most effectively decreased browning in 2nd week as compared to other combinations.

In case of plasma incubated with glucose concentration G₃ (5.5mM) showed maximum absorbance (fluorescence) of (0.89) at 1st week of incubation while value of absorbance decreased to its minimum (.222) in 4th week of incubation. I₂ showed minimum absorbance (fluorescence) in 3rd week (0.072) as compared to I₁ and I₃ at 37 °C in extract (Fig.3). It indicated that suitable amount of inhibitor (I₂) most effectively decreased browning in 3rd week as compared to other combinations.

Malus domestica extract effect on the basis of browning

- I₁ of extract showed minimum browning at glucose concentration of G₁ and G₂ than I₂ and I₃.
- I₂ showed minimum browning at glucose concentration of G₃ than I₁ and I₃ in extract.
- Minimum browning is shown by I₂ in *Malus domestica* extract.

Overall water extract of inhibitor (*Malus domestica*) showed that compound worked effectively and hence I₂ of extract showed better results.

Thiobarbituric Acid Test

Thiobarbituric acid test is used to measure the Glycation level. Here glycation levels were checked by this test for different concentration of glucose (G₁, G₂ and G₃) and inhibitor (I₁, I₂ and I₃) at 37°C.

Our result indicated that plasma incubated with G₁ (50mM) showed gradual increase in glycation and maximum glycation(10.14 mol/mol) occurs at 5th week of incubation. I₁ showed maximum inhibition (1.6 mole/mole) in 3rd week as compared to I₂ and I₃ at 37 °C in extract (Fig. 4). It indicated that suitable amount of hot inhibitor (I₁) most effectively inhibited glycation in 3rd week as compared to other combinations.

Plasma incubated with G₂ (25 mM) showed maximum level of glycation(8.182 mol/mol) at 5th week of incubation while decreased glycation level to (4.08 mole/mole) at 2nd week. I₁ showed maximum inhibition (1.571 mole/mole) in 3rd week as compared to I₂ and I₃ at 37 °C in extract (Fig. 5). It indicated that suitable amount of inhibitor (I₁) most effectively inhibited glycation in 3rd week as compared to other combinations.

Plasma incubated with G₃ (5.5 mM) showed maximum level of glycation (6.87 mol/mol) at 5th week of incubation while decreased glycation level to (3.28 mole/mole) at 1st week. I₃ showed maximum inhibition (0.89 mole/mole) in 1st week as compared to I₁ and I₂ at

37 °C in extract (Fig. 6). It indicated that suitable amount of inhibitor (I₃) most effectively inhibited glycation in 1st week as compared to other combinations.

Malus Domistica extract effect on the basis of glycation

- I₁ (extract as such) showed minimum glycation (maximum inhibition) at glucose concentration of G₁ and G₂ both in 3rd week than I₂ and I₃.
- I₃ of extract showed minimum glycation (maximum inhibition) at glucose concentration of G₃ in 1st week.
- Maximum glycation inhibition is shown by I₁ in *Malus domestica* extract.

On thorough study we came to conclude that samples having low browning (fluorescence) had also low level of glycation.

Enzyme linked Immunosorbent Assay (ELISA)

The results plotted, were obtained from ascorbic acid after performing ELISA at 37°C temperature and 5 weeks incubated in *in vitro* conditions.

The results indicate that G₁ (50mM) showed maximum Advance Glycation End Products (AGEs) formation (0.021µg) in 5th week of incubation while decreased Advance Glycation End Products (AGEs) formation (0.006µg) in 1st week. I₂ (200mmol) showed maximum inhibition (0.004µg) in 2st week as compared to I₁ and I₃ at 37 °C (Fig. 7). It indicated that suitable amount of inhibitor (I₂) most effectively inhibited Advance Glycation End Products in 2st week as compared to other combinations

Our result indicated G₂(25mM) showed maximum Advance Glycation End Products (AGEs) formation (0.023µg) in 5th week of incubation while decreased Advance Glycation End Products (AGEs) formation (0.008µg) in 2st week. I₂ (200mmol) showed maximum inhibition (0.006µg) in 2st week as compared to I₁ and I₃ at 37 °C (Fig. 8). It indicated that suitable amount of inhibitor (I₂) most effectively inhibited Advance Glycation End Products in 1st week as compared to other combinations

Our result indicates that G₃ (5.5mM) showed maximum Advance Glycation End Products (AGEs) formation (0.022µg) in 5th week of incubation while decreased Advance Glycation End Products (AGEs) formation (0.007µg) in 1st week. I₂ (200mmol) showed maximum inhibition (0.005µg) in 1st week as compared to I₁ and I₃ at 37 °C (Fig. 9). It indicated that suitable amount of inhibitor (I₂) most effectively inhibited Advance Glycation End Products in 1st week as compared to other combinations.

Malus domestica extract effect on the basis of ELISA

- I₂ (10 times diluted than I₁) of extract showed maximum inhibition of advanced glycation end product at glucose concentration of G₁ and G₂ than I₁ and I₃.
- I₃ showed minimum AGE at glucose concentration of G₃ than I₁ and I₂ in extract.
- Minimum AGE is shown by I₂ in *Malus domestica* extract.

Overall water extract of inhibitor (*Malus domestica*) showed that compound worked effectively and hence I₂ of extract showed better results.

Our results coincided with those of Nishigaki[33]who reported that Effect of fresh *Malus domestica* extract on glycated protein. In line with our results, it has also been proved that *Aloe vera* is a Hypoglycemic Drugs in Diabetes Mellitus [34-37].

Pearson[38] findings indicating that *Malus domestica* juice inhibits low density lipoprotein oxidation and Song [39] found Associations of dietary flavonoids with risk of Type 2 Diabetes. In accordance with our findings [40-42] also investigated Antioxidant and antiproliferative activities of common fruits. Our results are in accordance with Rendell[43] who reported the Inhibition of glycation of albumin and hemoglobin by acetylation *invitro* and *invivo*.

Table.1 Different combinations for Advance glycation end product inhibition

Sl.No	Combinations				
	Temperature 37°C				
1.	Buffer				
2.			Plasma		
3.			Glucose-1		
4.			Glucose-2		
5.			Glucose-3		
6.			Inhibitor I ₁		
7.			Inhibitor I ₂		
8.			Inhibitor I ₃		
9.	Glucose-1	+	Inhibitor I ₁		
10.	Glucose-1	+	Inhibitor I ₂		
11.	Glucose-1	+	Inhibitor I ₃		
12.	Glucose-2	+	Inhibitor I ₁		
13.	Glucose-2	+	Inhibitor I ₂		
14.	Glucose-2	+	Inhibitor I ₃		
15.	Glucose-3	+	Inhibitor I ₁		
16.	Glucose-3	+	Inhibitor I ₂		
17.	Glucose-3	+	Inhibitor I ₃		
18.	Plasma	+	Glucose-1		
19.	Plasma	+	Glucose-2		
20.	Plasma	+	Glucose-3		
21.	Plasma	+	Inhibitor I ₁		
22.	Plasma	+	Inhibitor I ₂		
23.	Plasma	+	Inhibitor I ₃		
24.	Plasma	+	Inhibitor I ₁	+	Glucose-1
25.	Plasma	+	Inhibitor I ₂	+	Glucose-1
26.	Plasma	+	Inhibitor I ₃	+	Glucose-1
27.	Plasma	+	Inhibitor I ₁	+	Glucose-2
28.	Plasma	+	Inhibitor I ₂	+	Glucose-2
29.	Plasma	+	Inhibitor I ₃	+	Glucose-2
30.	Plasma	+	Inhibitor I ₁	+	Glucose-3
31.	Plasma	+	Inhibitor I ₂	+	Glucose-3
32.	Plasma	+	Inhibitor I ₃	+	Glucose-3

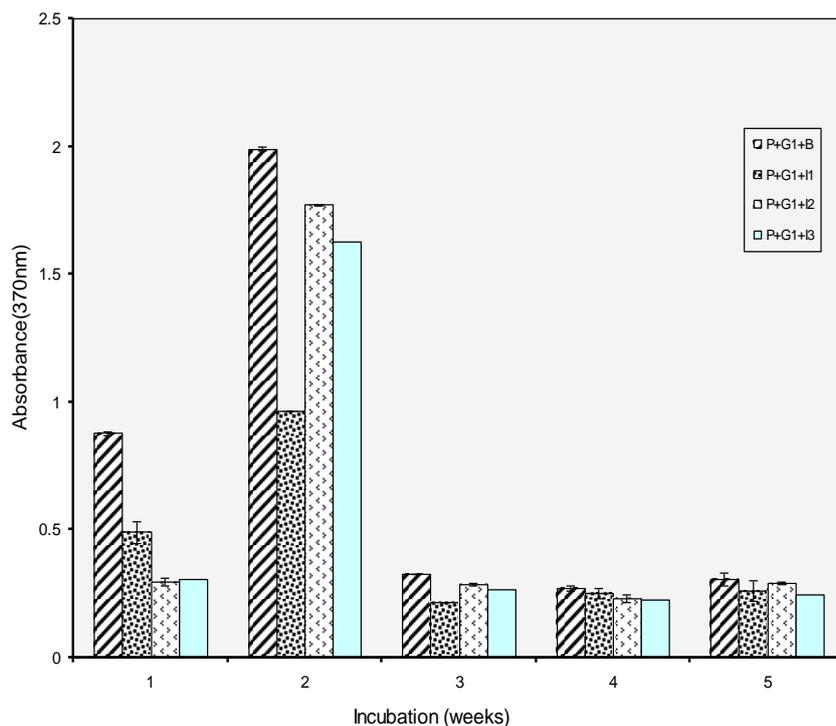


Fig. 1: Determination of browning at 37°C for 50 mM glucose (G1) in *Malus domestica*

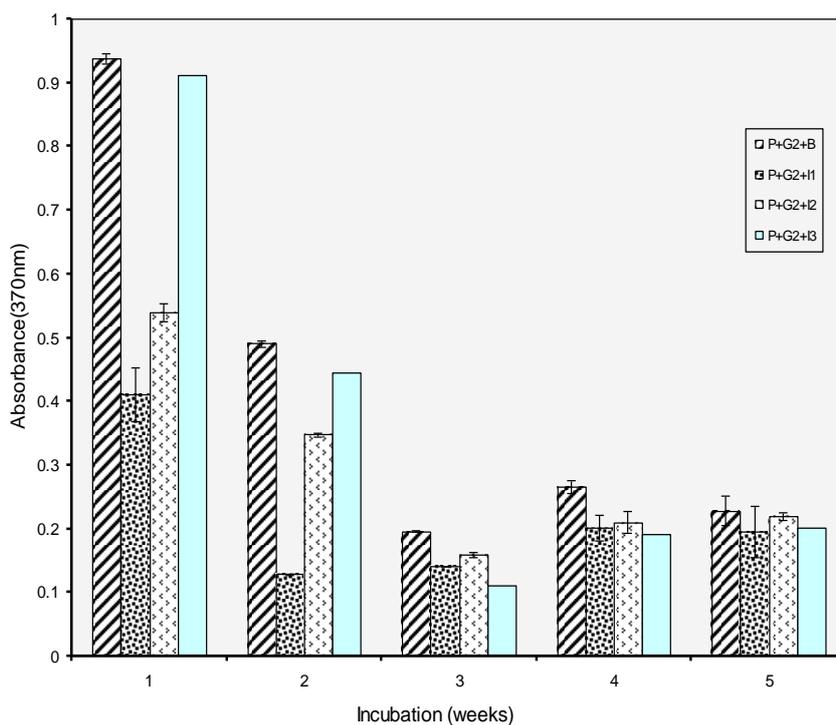


Fig. 2: Determination of browning at 37°C for 25 mM glucose (G2) in *Malus domestica*

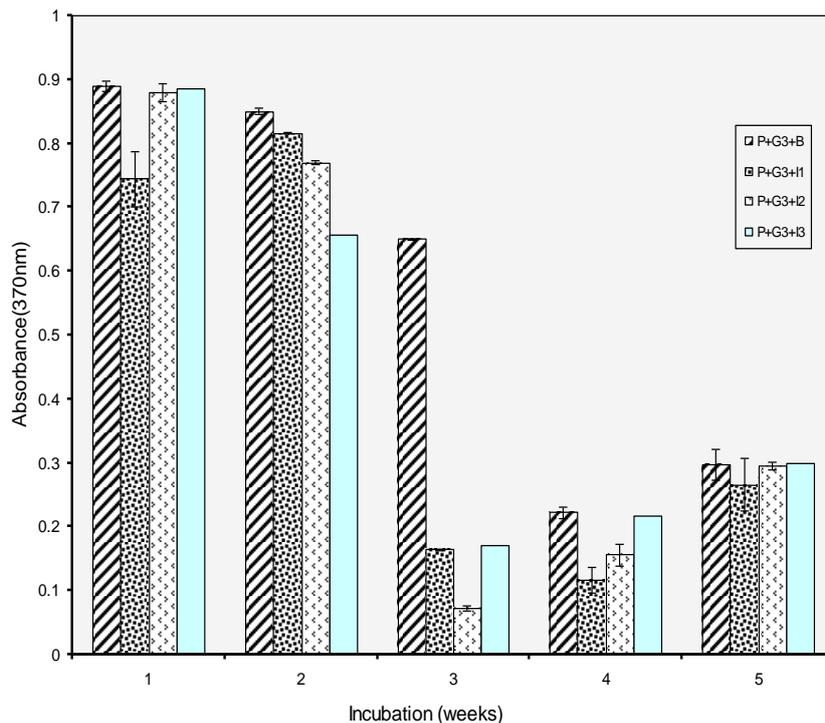


Fig. 3: Determination of browning at 37°C for 5.5 mM glucose (G3) in *Malus domestica*

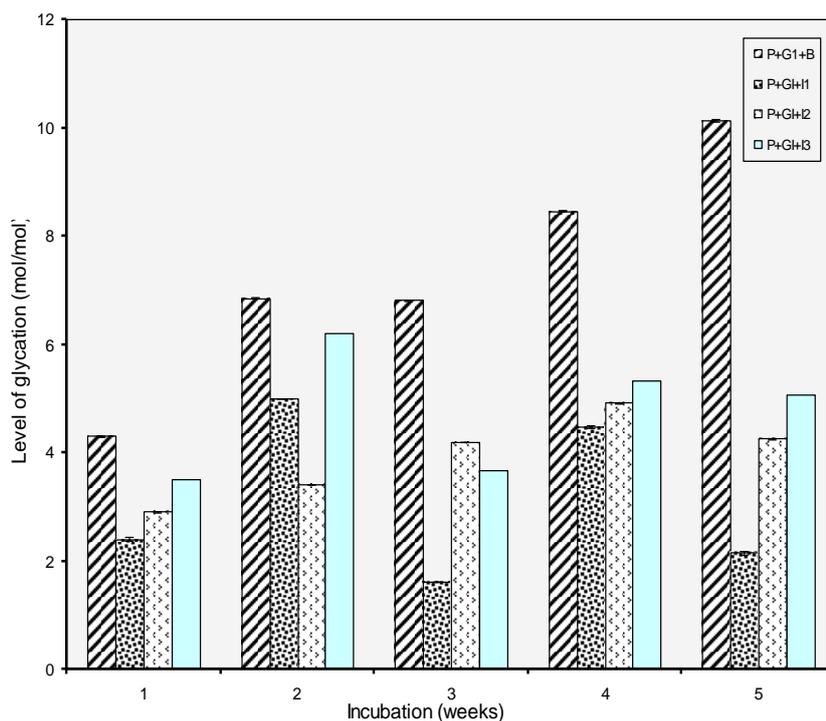


Fig.4: Determination of Glycation at 370C for 50 mM Glucose (G1) in *Malus domestica*

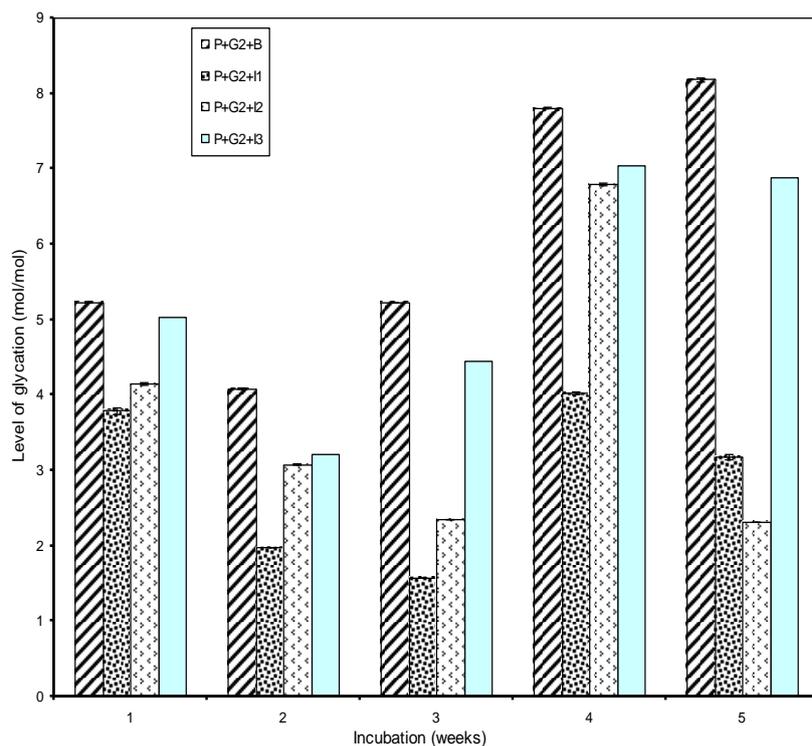


Fig. 5: Determination of Glycation at 370C for 25 mM Glucose (G2) in Malus domestica

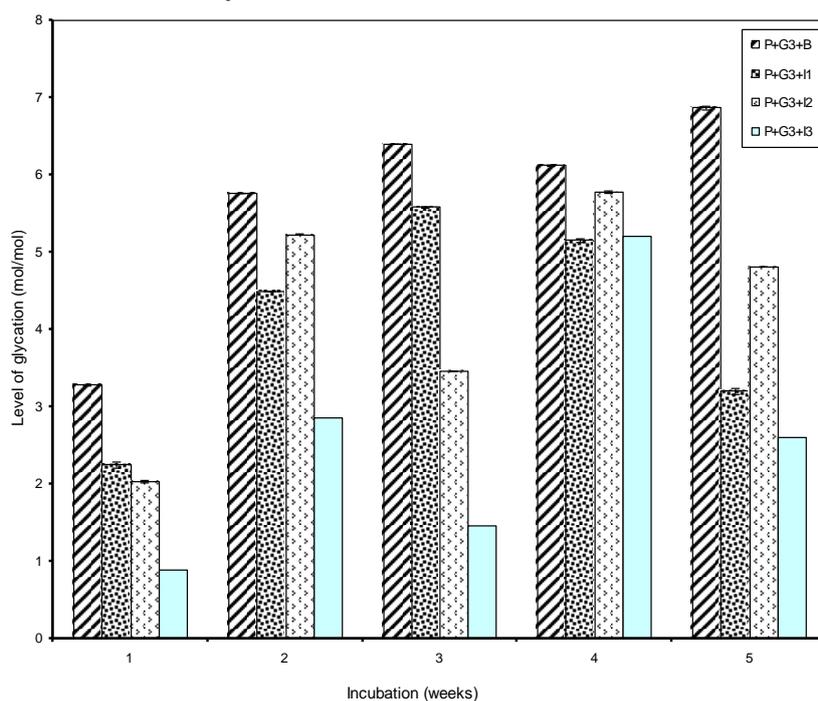


Fig.6: Determination of Glycation at 370C for 5.5 mM Glucose (G3) in MalusDomistica

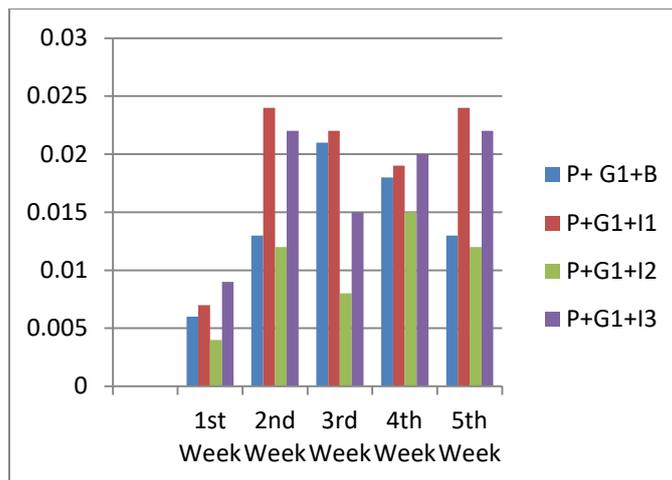


Fig. 7: Enzyme linked Immunosorbent Assay (ELISA) at 37°C for 50mM Glucose (G1)

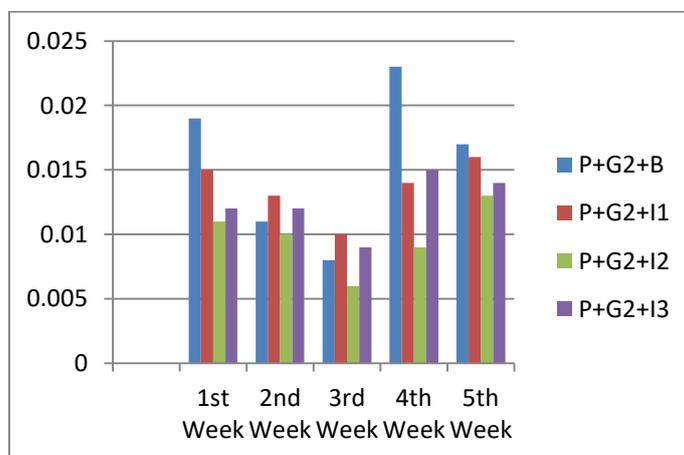


Fig. 8: Enzyme linked Immunosorbent Assay (ELISA) at 37°C for 25mM Glucose (G2)

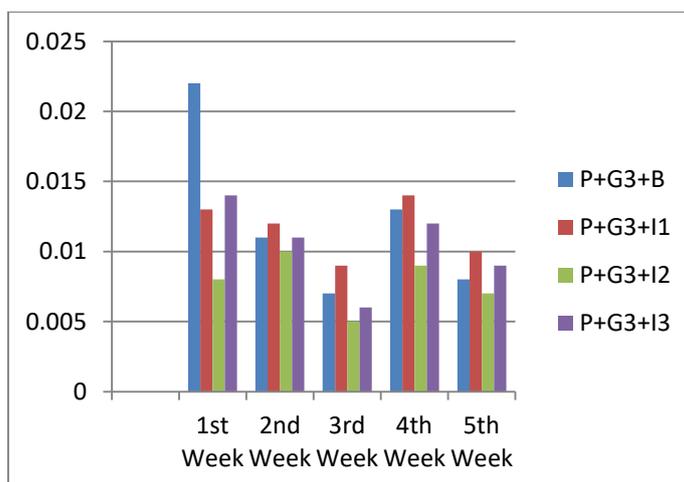


Fig. 9: Enzyme linked Immunosorbent Assay (ELISA) at 37°C for 5.5mM Glucose (G3)

Conclusion

“*Malus domestica*” is effective and efficient in lowering the glycation level in conditions when the level of glucose is high i.e. in diabetes. So the results indicate that in future “*Malus domestica*” can be used for lowering glucose level in the body.

REFERENCES

1. Ahmed N, Furth AJ; Failure of common glycation assays to detect glycation by fructose. Clin Chem., 1992; 38:1301-1303.

2. Rajbar S; An abnormal hemoglobin in red cells of diabetics. Clin Chem Acta., 1968; 22: 296-298.
3. Day JF, Thorpe SR, Baynes JW; Nonenzymatically glycosylated albumin. In vitro preparation and isolation from normal human serum. J Biol Chem., 1979; 254:595-597.
4. Iberg N, Fluckiger R; Non-enzymatic glycosylation of albumin in-vivo. Identification of multiple glycosylated sites. J Biol Chem., 1986; 261:13542-13545.
5. Jakus V, Hrciarova M, Carsky J, Krahulecand B, Rietbrock N; Inhibition of nonenzymatic protein glycation and lipid peroxidation by drugs with antioxidant activity. Life Sci., 1999; 65:1991-1993.
6. Miyata T, Oda O, Inagi R, Iida Y, Araki N, Yamada N *et al.*; beta 2-Microglobulin modified with advanced glycation end products is a major component of hemodialysis-associated amyloidosis. The Journal of clinical investigation, 1993; 92 (3): 1243-1252.
7. Huby, R, Harding JJ; Non-enzymatic glycosylation (glycation) of lens protein by galactose and protection by aspirin and reduced glutathione. Exp Eye Res., 1988; 47:53-59.
8. Makita Z, Radoff S, Rayfield EJ, Yang Z, Skolnik E, Delaney V *et al.*; Advanced glycosylation end products in patients with diabetic nephropathy. The New England Journal of Medicine, 1991; 325: 836-842.
9. Koschinsky T, He CJ, Mitsuhashi T, Bucala R, Liu C, Buenting *Cet al.*; Orally absorbed reactive glycation products (glycotoxin): an environmental risk factor in diabetic nephropathy. Proceedings of the National Academy of Sciences, 1997; 94 (12): 6474-6479.
10. Pertyńska MM, Głowacka E, Sobczak M, Cypryk K, Wilczyński J; Glycation end products, soluble receptors for advanced glycation end products and cytokines in diabetic and non diabetic pregnancies. Am J Reprod Immunol., 2009; 61(2): 175-182.
11. Oberley LW; Free radicals and diabetes. Free Radic Biol Med., 1988; 5:113-124.
12. Tiwari AK, Rao JM; Diabetes mellitus and multiple therapeutic approaches of phytochemicals. Present status and future prospects. Curr Sci., 2002; 83:30-38.
13. Baynes JW; Role of oxidative stress in development of complications in diabetes. Diabetes, 1991; 40:405-412.
14. Halliwell B, Gutteridge JMC; Lipid peroxidation, oxygen radicals, cell damage and antioxidant therapy. Lancet, 1994; 1:1396-1397.
15. Polidori MC, Stahl W, Eichler O, Niestroj I, Sies H; Profiles of antioxidants in human plasma. Free Radic Biol Med., 2008; 30:456-462.
16. Wohaieb SA, Godin DV; Alterations in free radical tissue defense mechanism in streptozotocin induced diabetes in rats. Diabetes, 1987; 36:1014-1018.
17. Larson RA; The antioxidants of higher plants. Phytochemistry, 1988; 27:969-978.
18. Coats BC, Ahola R; *Malus domestica* the Silent Healer, A modern Study of *Aloe vera*. Dallas, 1979; 4:110-115.
19. Davis RH, Maro NP; *Malus domestica* and Gibberellin Anti-Inflammatory Activity. Diabetes J of the American Podiatric Medical Association., 1989; 79:10-14.
20. He XJ, Liu RH; Triterpenoids Isolated from Apple Peels Have Potent Antiproliferative Activity and May Be Partially Responsible for Apple's Anticancer Activity. J Agric Food Chem., 2007; 55: 4366-4370
21. Rajasekaran S, Sriram N, Arulselvan P, Subramanian S; Effect of *Malus Domistica* extract on membrane bound phosphatases and lysosomal hydrolases in rats with streptozotocin. Diabetes, 2007; 62:221-225.
22. Bunyapraphatsara N, Yongchaiyudha S, Rungpitarangsi V, Choekchaijaroenporn O; Antidiabetic activity of *Malus domestica*. Clinical trial in diabetes mellitus patients in combination with glibenclamide. Phytomed., 1996; 3:245-48.
23. Chithra P, Sajithlal GB, Chandrakasan; Influence of *Malus Domistica* on the healing of dermal wounds in diabetic rats. J Ethnopharmacol., 1998; 59:195-201.
24. Vogler BK, Ernst E; *Malus domestica*. a systematic review of its clinical Effectiveness. British J of General Practice, 1999; 49:823-828.
25. Okyar A, Can A, Akev N, Baktir G, Sutlupinar N; Effect of *Malus domestica* on Blood Glucose Level in Type I and Type II Diabetic Rat Models. J Phytother., 2001; 15(2):157-161.
26. Rajasekaran S, Sivagnanam K, Subramanian S; Modulatory effects of *Malus domestica* extract on oxidative stress in rats treated with streptozotocin. J. Pharm and Pharmacol., 2003; 23:85-95.
27. Zhang EY, Swaan; Determination of Membrane protein Glycation in Diabetic Tissue. AAPS Pharm Sci., 1999; 1:20-35.
28. Aslam N, Sheikh MA, Rehman K, Nawaz H; Biochemical Profile Indicative of Insulin Resistance in Nondiabetic and Diabetic Cardiovascular Patients. International Journal of Agriculture & Biology, 2011; 14(1):126-130.
29. Gornall AG, Bardawill CS, David MM; Determination of serum proteins by means of

- biuret reaction. J Biol Chem., 1949; 177: 751-766.
30. Furth AJ; Methods for assaying non enzymatic glycosylation: a review. Anal Biochem., 1988; 175: 347-360.
 31. Zhang J, Slevin M, Duraisamy Y, Gaffney J, Smith AC, Ahmed N; Comparison of protective effects of aspirin, D-penicillamine and vitamin E against high glucose-mediated toxicity in cultured endothelial cells. Biochim Biophys Acta., 2006; 1762 (5): 551-557.
 32. Steel RGD, Torrie MJH, Dickey DA; Principles and Procedures of Statistics: A Biometrical Approach. McGraw Hill Book Co., Inc. New York, USA, 1997.
 33. Nishigaki I, Raj Kapoor B, Rajendran P, Venugopal R, Ekambaram G, Sakthisekaran Det *al.*; Effect of fresh apple extract on glycated protein/iron chelate-induced toxicity in human umbilical vein endothelial cells in vitro. Nat Prod Res., 2010; 24(7):599-609.
 34. Tongia A, SK Tongia, M Dave; Phytochemical Determination and Extraction of *Aloe vera* and Its Hypoglycemic Potentiation. Oral Hypoglycemic Drugs in Diabetes Mellitus (NIDDM), 2004; 48(2):241-244.
 35. Tanaka M, Misawa E, Ito Y, Habara N, Nomaguchi K, Yamada M *et al.*; Identification of five phytosterols from *Aloe vera* gel as anti-diabetic compounds. J Biol Pharm Bull., 2006; 29:1418-1422.
 36. Ojewole JA. Adewole SO, Olayiwola G; Hypoglycaemic and hypotensive effects of *Aloe vera* plant a Platel hypoglycemic agents. J Nahrung., 2006; 41:68-74.
 37. Can A, Akev A, Ozsoy A, Bolkent A, Arda BP, Yanardag B, Okyard CA; Effect of *Aloe vera* leaf gel and pulp extracts on the liver in type-II Diabetic rat models. Biol Pharm Bull., 2004; 27:694-698.
 38. Pearson D, Tan C, German B, Davis P, Gershwin M; Apple juice inhibits low density lipoprotein oxidation. Life Sci., 1999; 64:1919-1920.
 39. Song Y; Associations of dietary flavonoids with risk of Type 2 Diabetes, and markers of Insulin Resistance and Systemic Inflammation in Women: A Prospective Study and Cross Sectional Analysis. Journal American College of Nutrition, 2005; 24 (5): 376-384.
 40. Wolfe K, Wu X, Liu RH; Antioxidant activity of apple peels. J Agric Food Chem., 2003; 51:609-614.
 41. Liu RH, Eberhardt M, Lee C; Antioxidant and antiproliferative activities of selected New York apple cultivars. New York Fruit Quarterly, 2001; 9:15-17.
 42. Sun J, Chu Y, Wu X, Liu RH; Antioxidant and antiproliferative activities of common fruits. J Agric Food Chem., 2002; 50:7449-7454.
 43. Rendell M, Nierenberg J, Brannan C, Valentine JL, Stephen PM, Dodds S *et al.*; Inhibition of glycation of albumin and hemoglobin by acetylation in vitro and in vivo. J Lab Clin Med., 1986; 108 (4): 286-293.