Research article
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Development of Functional Foods to Cure Diabetes from Seasonal Fruits and Vegetables

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ABSTRACT:
Functional foods are chemical compounds that are naturally bioactive and have health-giving preventive medicine because of their medicinal properties and nutritional composition. Epidemiologic research has established abundant health effects of functional food utilization, such as lowering hyperglycemic index, anti-cholesterol, the decline in cancer risk, etc. This research work relates to inventing a novel, economically feasible, and preferably biologically active antidiabetic functional food product from the combination of the four most dominant, low-cost, edible plant parts. These are *Allium sativum* (Garlic), *Emlica officinalis* (Amla), *Ceylon zeylanicum* (cinnamon), and *Momordica charantia* (bitter gourd). The main goal of this study is to evaluate anti-hyperglycemic activity, especially in Type II diabetes (non-insulin-dependent). During the experimental trials, oral feeding of the functional food supplement for 28 days to Allaxon- induced diabetic rabbit's decreased hyperglycemic effects significantly. The functional food supplement produced a significant hypoglycemic effect in all three doses after 28 days. The most effective dose found was 75mg/kg body weight. The maximum fall of 68.93% was observed after oral administration at a 75mg/kg body weight dose. Functional food products have also been analyzed for macronutrients carbohydrates, protein, fat, fiber, and micronutrients: vitamins, minerals, and total phenols. All the macro and micronutrients were found in reasonable quantities.

Keywords: Antidiabetic functional food, anti-hyperglycemic activity, Macronutrients

Highlight:
- ✓ Medicinal plants,
- ✓ **r**eplacement of synthetic drug formulation,
- ✓ control of diabetes worldwide,

1. Introduction:

Nowadays, medicinal plants are being broadly utilized for different disorders, and due to some specific reasons, medicinal plants have been explored for antidiabetic impacts. Diabetes is a global problem and is one of the oldest disorders known to humanity. It has been presumed that Diabetes Mellitus results from inherent stresses in a modern lifestyle, and the rising incidence of diabetes is becoming a significant public health problem affecting millions of individuals worldwide (Evert et al., 2019). The prevention of diabetes still lies in the realm of the future, and until then, millions will continue to suffer from this disease (American Diabetes Association. (2018). The World Health Organization (WHO) predicts that by the year 2025, almost 300 million people will suffer from diabetes mellitus. In Pakistan, diabetes is a predominant illness and has the seventh-largest diabetic populace in the World and is anticipated to require the fourth put till 2025. Diabetes mellitus can be defined as a group of metabolic diseases characterized by chronic hyperglycemia resulting from defects in insulin secretion, insulin action, or both, resulting in impaired function of carbohydrate, lipid, and protein metabolism. (W.H.O. 2014; Qaseem et al., 2018; National Collaborating Centre for Chronic Conditions 2008). Attention has been paid to utilizing eco-friendly and bio-neighborly plant items to anticipate and remedy distinctive human unremitting illnesses. (Chandran et al., 2016; Chandran et al., 2015). World's 80 % population has confidence in conventional drugs, primarily plant-based, with their hostility to diabetic possibilities for their essential wellbeing care (Chouaibi et al., 2019; Gonai et al., 2017). Due to their antioxidant, anti-fungal, anti-parasitic, antibiotic, anti- microbial, and anti-viral activities either individually or in combinations, natural plant-based products are proven to provide symptomatic relief and assist in regulating the Beta cells and maintain normal glucose levels (Cheng et al., 2014; King et al., 1998). In recent medicine and conventional systems, medicinal plants provide us with precious therapeutic substituents. More than four hundred long-established plants show therapeutic actions for diabetes reported. (Osinubi et al., 2006; Nazar, 2006). *Momordica Charantia* (Bitter Melon), cinnamon, *Trigonella* (cloves) *Foenum graecum* (Fenugreek), and *Allium cepa* (onion) *Amla, (Eblica officinalis*), have been utilized for the cure of diabetes, relish, and flavor development in food preparations. (Rasouli et al., 2020; Perla, & Jayanty 2013).

Although there are many herbal formulations/supplements are available worldwide but the present invention is innovative and quite different from the other herbal formulations because it can be used as a potential antidiabetic functional food product /supplement which will decrease the hyperglycemic effects significantly in Patients suffering from diabetes Mellitus (Type-2), This unique functional food product has been formulated in such a combination of

extracts, especially in crude powder form comprising four economically feasible indigenous antidiabetic natural plant components so that it can provide additional nutrients beyond the basic needs are encapsulated (Naveen et al., 2021; Brunström, & Carlberg 2016). Vegetables and natural products can offer assistance to combat cardiovascular disorders, cancer, diabetes and anticipate or delay the onset of maturing impact. Fruits/vegetables like bitter-gourd, *Syzygium cumini*, amla and garlic have great therapeutic impacts. (Brunström, & Carlberg 2016; Zheng et al., 2017).

The present study aimed to discover an innovative and economically feasible crude functional food product from the combination of four primary sources of everyday, low cost, indigenous plant parts and antidiabetic components (alcoholic and aqueous extracts powder of Allium sativum L. (Garlic), *Amla (Eblica officinalis*) and C. zeylanicum (Ceylon cinnamon) Bitter gourd (Momordica charantia) and shed lights on its hypoglycemic activities on allaxon induced diabetic rabbits. During the study, it was observed that oral feeding of the natural functional food product for 28 days to allaxon induced diabetic rabbits decreased hyperglycemic effects significantly up to 68.93% (Fox et al., 2015; Li et al., 2021).

2. Material and Method:

2.1 Collection of indigenous plants parts:

All plant parts were purchased from the local market.

Formulation – 1:

1. *Momardica chirantia* (Bitter gourd) 300mg
2. *Allium Sativum L*. (Garlic) 200mg
3. *Phyllanthus emblica Linn*.(amla) 225mg
4. *Ceylon.zeylanicum* (cinnamon) 275mg

Each plant part was blended in alcohol and water to obtain its extracts to produce an antidiabetic functional food composition of the invention in powder form. Extracts were filtered through cloth. Then the resultant extracts were dried under slow heat below 50 ^{o}C and then ground into a fine powder. These powders were then mixed in relative amounts.

Formulation – 2:

1. *Momardica chirantia* (Bitter gourd) 250mg
2. *Allium Sativum L.* (Garlic) 150mg
3. *Phyllanthus emblica Linn*.(amla) 200mg
4. *Ceylon.zeylanicum* (cinnamon) 225mg

Each plant part was blended in alcohol and water to obtain its extracts to produce an antidiabetic functional food composition of the invention in powder form. Extracts were filtered through cloth. Then the resultant extracts were dried under slow heat below 50 ^{o}C and then ground into a fine powder. These powders were then mixed in relative amounts.

Formulation – 3:

1. *Momardica chirantia* (Bitter gourd) 200mg
2. *Allium Sativum L*. (Garlic) 125mg
3. *Phyllanthus emblica Linn*.(amla) 150mg
4. *Ceylon.zeylanicum* (cinnamon) 200mg

Each plant part was blended in alcohol and water to obtain its extracts to produce an antidiabetic functional food composition of the invention in powder form. Extracts were filtered through cloth. Then the resultant extracts were dried under slow heat below 50 ^{o}C and then ground into a fine powder. These powders were then mixed in relative amounts.

3. Results and discussion:

The effect of various doses of antidiabetic functional food products on allaxon induced diabetic rabbits has been studied, and the following results received which were reported in Fig.1.

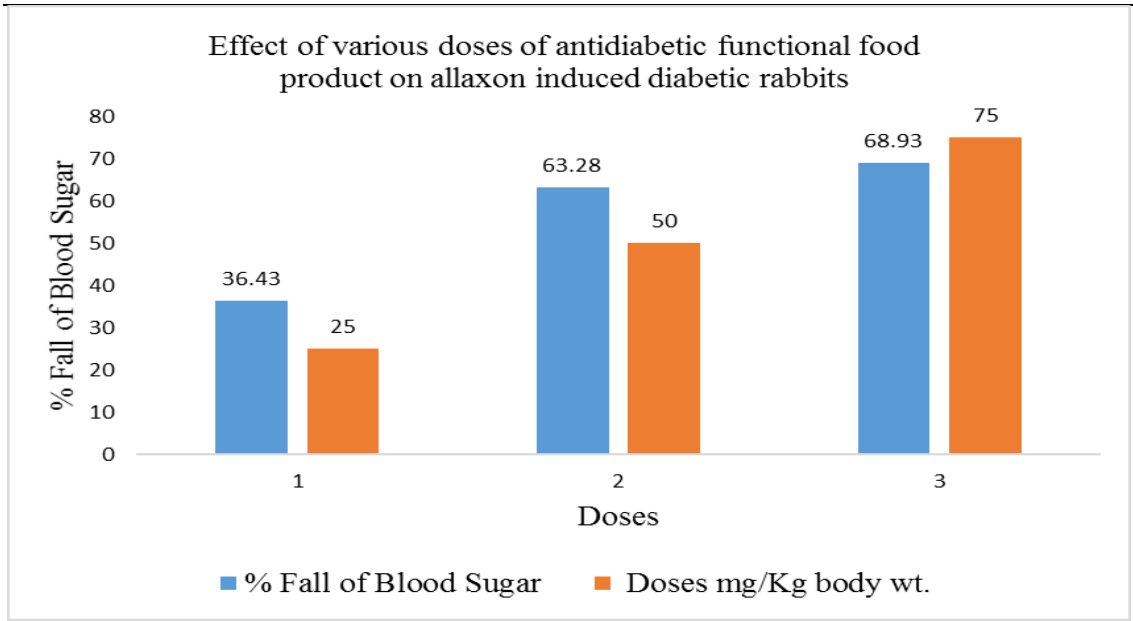

Figure 1: The effect of various doses of antidiabetic functional food product on allaxon induced diabetic rabbits.

Results in Fig.1 showed that the oral feeding of the functional food supplement for 28 days to Allaxon- induced diabetic rabbits significantly decreased hyperglycemic effects. The functional food supplement produced a significant hypoglycemic effect in all three doses after 28 days. The most effective dose found was 75mg/kg body weight. The maximum fall of 68.93% was observed after oral administration at a 75mg/kg body weight /dose followed by no toxic effects. Chandran et al. (2016) reported antidiabetic activity of *Syzygium calophyllifolium* in Streptozotocin-Nicotinamide (STZ-NA) induced diabetic rats where they observed the same results in bark methanol extract under 100 and 200 mg/kg.

3.1 Feeding trials on 39 volunteers:

The feeding trial on 39 volunteers was also conducted and completed to test the functional foods related to the plants (Table-1 and Fig.2). to show the recent picture about diabetic patients. Results showed that fruits and vegetables help in reducing diabetes, as previously reported by Naveen et al. (2021) where they expose medicinal plants can assess in human diabetic subjects, produced either in combination with a few medicinal plants or alone.

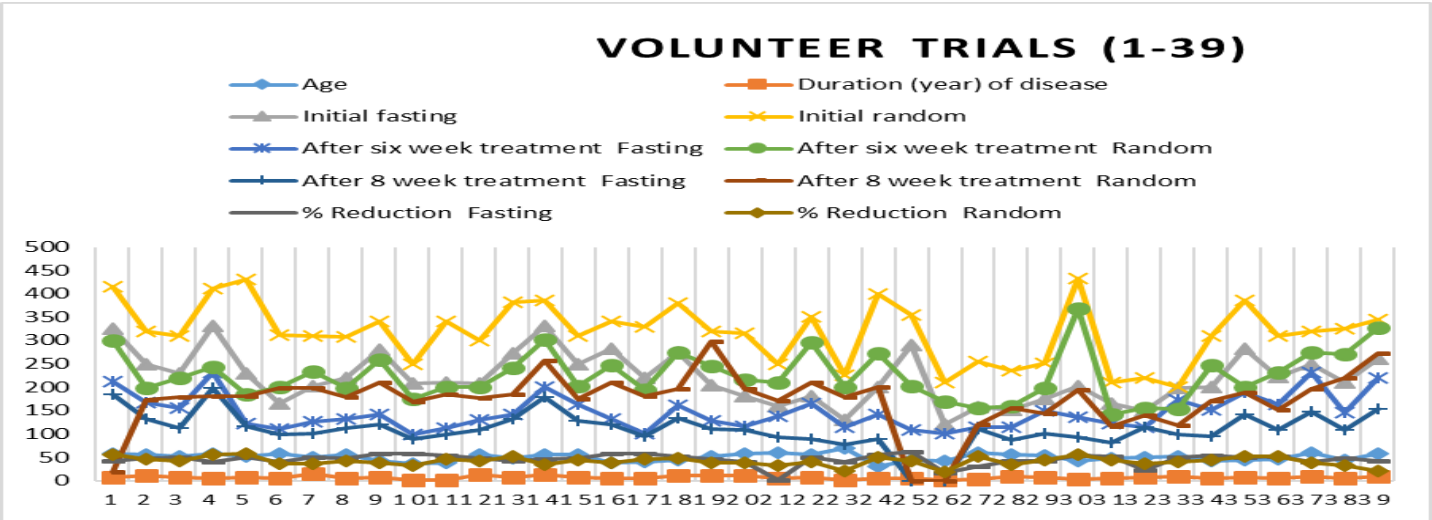

Figure 2: Graphical representation of Volunteer Trials(1-39)

Table-1: Volunteer Trials (1-39)

Sr. No	Age	Duration (year) of disease	Initial fasting	Initial random	After six weeks of treatment		After 8 weeks of treatment		% Reduction	
					Fasting	Random	Fasting	Random	Fasting	Random
1	57	6	325	416	212	300	185	18	43.07	56.73
2	55	10	250	319	168	198	132	172	47.2	46.08
3	52	6	230	310	156	219	112	178	49.09	42.58
4	58	5	332	412	231	243	198	181	40.36	56.06
5	51	6	230	431	122	185	116	181	49.56	58.06
6	57	5	165	312	110	200	98	198	40.60	36.53
7	50	15	202	310	127	234	101	198	50.00	36.12
8	56	5	219	308	132	198	112	178	48.85	42.20
9	42	6	280	340	141	258	120	210	57.14	38.23
10	36	2	209	250	99	175	88	170	**57.89**	32.00
11	38	2	210	340	112	201	99	185	52.85	45.58
12	56	12	208	300	129	201	109	176	47.59	41.33
13	48	6	272	382	142	241	132	184	41.47	51.83
14	56	12	332	386	201	301	179	256	46.08	33.67
15	56	7	250	310	164	202	128	175	48.80	43.50
16	38	5	282	341	131	247	121	210	57.09	38.41
17	40	5	220	330	101	195	94	180	57.27	45.45
18	45	10	275	380	162	275	133	196	51.63	48.42
19	52	10	205	320	128	245	110	298	46.34	38.12
20	58	10	180	315	116	215	108	196	**40.00**	37.70
21	60	5	160	250	138	210	92	171	**42.5%**	31.6
22	56	7	180	350	165	295	89	210	**50.55**	40
23	70	2	130	225	115	201	77	178	**40.76**	20.88
24	30	5	200	400	141	273	88	201	**56**	49.75
25	45	5	290	354	109	203	---	---	**62.41**	42.65
26	42	2	120	210	100	169	---	---	**16.66**	19.52

27	60	3	158	254	115	155	110	121	**30.37**	52.36
28	55	9	152	235	115	160	87	155	**42.76**	34.04
29	54	7	175	252	150	198	101	143	**42.28**	43.25
30	42	3	202	432	135	368	92	195	**54.45**	54.86
31	48	5	165	210	122	142	81	116	**50.9**	44.76
32	50	7	150	220	115	155	115	140	**23.33**	36.36
33	51	9	198	200	172	153	98	119	**50.50**	40.5
34	43	5	200	310	152	248	94	171	**53**	44.83
35	44	7	283	385	189	201	142	188	**49.82**	51.16
36	46	5	222	310	164	231	109	151	**50.90**	51.29
37	59	8	250	320	231	275	148	196	**40.8**	38.75
38	45	5	210	325	145	271	109	220	**48.09**	32.30
39	57	9	260	345	219	328	153	272	**41.15**	21.15

The formulation of an antidiabetic functional food product for diabetic patients, especially Type-2 includes *Momardica chirantia* (Bitter guard) 25-300 mg/kg b.w *Allium Sativum* L. (Garlic) 25-200mg/kg b.w *Phyllanthus emblica Linn*.(Amla) 25-225 mg/kg b.w *Ceylon.zeylanicum* 25-275 mg/kg b.w respectively. All act as a stimulant to the beta cells of Langerhans islets of the pancreas to secrete more insulin and increase the utilization of sugars in the body cells. The oral feeding of the natural functional food product for 28 days to Allaxon induced diabetic rabbit's decreased hyperglycemic effects significantly up to 68.93%, comprising between 0.5 and about 1.0 gm. *Momardica chirantia* crude extract powder at least two times a day because Charantin has been found to have blood sugar bringing down capacity, similar to that of insulin , and can be utilized to treat patients with diabetes. The dependable compound for this activity is charantin comprising between about 50-200 mg/k b.w *Ceylon.zeylanicum* (cinnamon) extract powder at least two times a day. The cinnamic aldehyde content in cinnamon is responsible for preventing the onslaught of diabetes by regulating insulin production in the body. In animals, 50-200 mg/kg b.w *Phyllanthus emblica* Linn. (amla), extract powder at least three times a day. The amla chromium content is responsible for preventing diabetes by activating the pancreatic cells to produce insulin.

4. Conclusion:

It was concluded that the functional food contents in different edible plants could replace the synthetic drug formulation to control diabetes worldwide with healthier effects on patients

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Conflict of Interest

The corresponding author declares no conflict of interest among Authors

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