CHAPTER V
SUMMARY AND CONCLUSION

Antioxidants are substances that work in different ways to protect cells from biochemical damage (Preethi and Nandini, 2005). Kaur et al., (2004) suggest that increasing intake of dietary antioxidants may help to maintain an adequate antioxidant status and therefore the physiological functions of a living system. According to WHO 2005, India has 30 million diabetes subjects, which is 15 percent of total diabetics worldwide. Since India is the diabetic capital it is very essential to study on the dietary aspects of diabetic patients in our state. To measure the socio-economic, dietary, life style, health and clinical status of diabetic patients and to analyse the antioxidant status of NIDDM, IDDM and Non-diabetic subjects and also to estimate the impact of food supplementation on the antioxidant status of diabetic patients; a study was conducted on the “Antioxidant Status of Subjects with Diabetes Mellitus”

The study comprised of diabetic as well as non diabetic subjects above 30 years of age including both men and women selected from diabetic clinics. The findings of the study are summarized below:

Highest proportion (40.75 percent) of the subjects with Diabetes Mellitus is from the age group (51-60 years). Among the Type-I diabetic subjects, more than 15 percent are below 40 years of age, whereas the corresponding percent of Type-II subjects are only half of it (7.00 percent). The sex-wise distribution of subjects with Diabetes Mellitus shows that the proportion of males and females are almost equal. This shows the increasing prevalence of women diabetic patients in India. High prevalence of diabetics is found among the city dwellers (58.50 percent). Only 29.75 percent has diabetes in rural area.

As far as educational status is concerned, majority of them have education up to high school level and 28 percent of the subjects are either graduates or professionals and post graduates. It can also be seen that 43.5 percent of the subjects have government job and more
than 48 percent of the diabetics is in the sedentary category. Monthly income of majority (75.25 percent) of the subjects is between Rs. 2000 and Rs.10,000. Majority (80.75 percent) of the subjects belongs to families having members four and below.

Body Mass Index (BMI) indicates that more than 60 percent of both the male and female diabetic patients are obese. The subjects under the risk of obesity (over weight) include 26.75 percent of males and 22.41 percent of females. Grade I obesity is found higher among the females (32.01 percent) than in males (25.62 percent) while, the percent of male subjects (10.20 percent) with Grade II obesity is higher than the female subjects (9.92 percent). The BMI of 3.56 percent of males and 5.91 percent of females were below normal, which can be denoted as under nutrition.

Waist hip ratio shows that the health of the patients is at risk; though the percent of high-risk group is negligible (3.03 percent) proper attention must be taken to manage the situation from becoming worse. Huge majority (97.15 percent) of diabetic subjects are at moderate risk. Waist hip ratio of female diabetic subjects shows that 98 percents are in the ratio between 0.8 and 0.85 indicating moderate risk among the women.

In general (including type-I and type-II) about 71.75 percent of the subjects have inherited the disease from their family while 28.25 percent are new diabetics without any familial inheritance. Among the type-I diabetes 71.00 percent inherited the disorder from their family while 29.00 percent acquired the disorder without any inheritance. A similar proportion can be noticed among the type-II patients also, those with inheritance accounts to 72.50 percent and those in non-inherited section accounts to 28.25 percent.

The symptoms of diabetes first experienced at the onset of the disorder shows that each subject suffered more than one symptom. Type-I and type-II subjects faced almost same sufferings at the onset of the disorder. Polydipsia (81.50 percent), polyphagia (65.25 percent) and polyuria (64.25 percent) are the most commonly found symptoms. Others sufferings include tiredness (53.75 percent), headache (41.50 percent)
percent), weight loss (28.75 percent), delayed wound healing (27.75 percent), skin disease (27.75 percent), body pain (19.75 percent), giddiness (11.75 percent) and burning sensation on extremities (10.25 percent).

Majority (51.50 percent) of the subjects have accepted the fact that better control the disease requires a defense combination of intake of drugs, daily exercise and diet control. Diet and drugs are found beneficial by 29.75 percent of the subjects.

The study shows that 31.50 percent have no diabetic complication and hence can hope to have a better quality of life. The most commonly found diabetic complications are retinopathy and neuropathy (16.50 percents). The sufferers of single diabetic complications like neuropathy (14.00 percent), retinopathy (10.00 percent), diabetic gangrene (1.25 percent), diabetic foot (1.25 percent), renal infection (0.75 percent) and other illnesses (0.75 percent) should have a watch on the disease, so that it is controlled well. Multiple complications in diabetic patients need intensive care and proper guidance. Retinopathy, neuropathy, nephropathy, diabetic Gangrene, and diabetic-foot hit 0.25 percent of the subjects. Seven percent suffered from Retinopathy, Neuropathy, Diabetic Gangrene and Diabetic Foot.

High blood pressure is a symbolic representation of underlying cardiac diseases; 15.75 percent of the subjects suffer from blood pressure and 8.5 percents with high cholesterol and 7.25 percent with arthritis. It is very pathetic to have many diseases together; 0.5 percent suffered from heart disease, hyper tension, hyper cholesterolemia, asthma and arthritis and 0.25 percent suffers from hyper tension, hyper cholesterolemia, asthma, arthritis, migraine.

Though the subjects know that intake of stimulants are injurious to health they drink alcohol (5.75 percent), smoke (3.75 percent) and chew tobacco (0.75 percent). Four percent of the subjects do take both-smoke and drink alcohol. It is found that 55.50 percent does daily exercise, while 44.50 percent do no undergo daily exercise. This itself can be a causative factor for the increase of the huge diabetic
population in the country. Among those who take daily exercise 44.00 percent of the subjects walk daily for an average duration of forty five minutes per day, 18 percent practice yoga for sixty minutes, while a combination of walking and yoga of is accepted by 28.50 percents of the subjects. Only a few subjects perform vigorous physical activities like jogging (2.05 percent, performed for durations of 30 minutes), running (0.05 percent performed for durations of 15 minutes) and involve in games (6.05 percent performed for durations of 80 minutes).

Tension is the major factor that tampers the mental health in majority of the subjects (42.00 percent). Tension leads to sleeplessness (33.75) and delayed mental programming and leads to depression in the critical stage. Stress in ones work place and at home may alter the quality of life among 10.00 percent of the subjects. Family problems (8.25 percent), death of dear ones (1.00 percent), anxiety (3.00 percent), worries (5.75 percent), financial constrains (3.50 percent), and fear (3.25 percent) may contribute to psychological instability among the subjects.

Non-vegetarians (94.50 percent) are found to be more in number than the vegetarians (5.50 percent). It is interesting to note that majority of the subjects consumed food prepared through boiling (98.3 percent) and steaming (95 percent) while, fried (7.8), raw (3.8 percent), sautéed (1.5 percent), grilled (1 percent) and baked food (0.5 percent) are found to have less acceptance.

Parboiled rice (100 percent) and wheat flour (89.5 percent) are consumed for more than twenty five days a month. The consumption frequency of pulses and legumes shows that sprouted pulses are consumed for less than five days a month. In the case of dry pulses bengal gram is the most frequently consumed pulse compared to green gram, cow pea and soya bean. Curd and buttermilk is the most frequently consumed food stuff among the third group with a score of 2627.50. it is consumed daily by 62.75 percent of the diabetic subjects while 37.25 percent consume it for more than nineteen days a month.

Milk which is an integral part of the daily routine is consumed almost daily. The consumers of pasteurized toned milk accounts for
68.5 percent, while 23 percent purchase it from milk vendors. Consumption of pure cow’s milk from believable source is only 6.5 percent. Milk powder, Cheese, Butter, Panner are least consumed. Fish and sea food which includes Herring Indian, Tuna, Mackerel, Sardine and Anchovy are the commonly consumed sea food; 24.5 percent consume it for more than twenty five days a month. Among meat egg and poultry hen’s scored the maximum with a daily consumption of 61.75 percent.

Beef and Chicken are preferred more to Mutton and pork. A few diabetic subjects never consume beef (16.25percent) or chicken (6.5percent). The Intake of quails egg (91.75 percent do not) and duck’s egg (99.25 percent) are also rare. Ripe plantain is the only fruit consumed for more than twenty five days by the subjects (56 percent). Majority are under the fear of increasing blood sugar on consuming fruits. Grapes, pineapple and orange are also rarely consumed.

Analysis of the leafy vegetables section shows that curry leaf is the only leafy vegetable used for more than twenty five days in a month by cent percent subjects. But the quantity consumed is very less approximately one or two grams per day, which is negligible. Drumstick leaves and amaranthus are consumed more often compared to ariakeera, and agathi. Huge majorities (98.75) do not consume amaranth spined and is unaware of its nutritional significance.

Other vegetables are included in the daily menu to inculcate variety and nutrient quality. They are selected in rotation, according to the seasonal availability and individual preferences. Among the most commonly used oils, coconut oil secured first priority compared to other oils. Even though there exists coconut oil controversy 98.25 percent of the subjects consume it daily. Gingelly oil and Sunflower oil are the next popular forms of cooking oil being used daily. Groundnut oil and palm oil is not accepted in the dietary regimen of 87.25 percent and 89.50 percent of the subjects respectively.

Ghee and vanaspathi are less commonly used which might be due to its cholesterol stimulating factor. It is interesting to note that none of the subjects consumed mustard oil. Coconut which is the taste
maker of almost all Kerala dishes is consumed daily by cent percent subjects, but ground nuts, cashew nuts, gingelly seeds and almonds are less frequently consumed. The section of sweets and sugars are to be kept at bay by the diabetic patients, but a margin of subjects (2.25 percent) consumes sweetened products. By the arrival of Diabetic sugars some of the subjects (6.25 percent) consume it on regular basis along with tea and coffee.

Processed and preserved food like pappads. Pickles, squashes, jams and jellies are also consumed occasionally. Neutraceutical products like health drinks and herbal products are consumed by less than nineteen percent of the subjects. The neutraceutical product Spirullina is totally an alien for all the subjects. Not even a single subject was under the practice of consuming the product.

Beverages are part of our daily routine. Tea and coffee, often taken along with the breakfast cereals attained first priority. Other beverages with special importance to our society are fruit juices, alcohol, wine and soups with weighted index score 174.50, 28.50, 17.50 and 4.25 respectively. The intake of carbonated beverage intake is significantly negligible compared to other beverages, as it is not found to be a common practice among the subjects.

Type-I subjects consumed lesser amount of food; the possible reason may be due to proper orientation by the diabetologists to manage type-I diabetes. Cereal consumption is found higher among males than females and heavy workers which is necessary for their daily activity. Consumption of green leafy vegetables and other vegetables was found less as majority of the subjects do not consume it daily. The average rate of pulses and flesh food consumption for all the groups is almost the same and is no less than 50.00 g per day. Though sugar and jaggery is banned for the diabetic subjects an average of 5-15 g is consumed often. Fruits are consumed only in moderation.

The analysis of 24 hour recall method found that type-I patients have a better outlook in dietary regimen compared to their type-II counterparts as the calorie, carbohydrates, proteins, and fat intake is
lesser than the type-II patients. Male subjects consume more amounts of all nutrients than females. Intake of calories is lesser than the RDA. Protein and fat intake is high.

Awareness regarding diabetes and antioxidants were collected from the analysis of 30 different statements. The statements were divided into four main groups. The first group statements were related to cause of diabetes, second group on symptoms and complications form, third group related to control of diabetes and the fourth group of statements related to information on antioxidant and dietary knowledge among Diabetics. Multiple regression analysis was carried out by backward selection method with awareness score as continuous numerical dependent variables and nine socio-economic characteristics as independent variables. Subjects have maximum awareness (9.15) on the symptoms and complications related to diabetics mellitus followed by control and management of diabetics (3.29). The awareness regarding Antioxidant and dietary management is found to be comparatively low (-1.22). The level of awareness among the subjects after counseling increased from 12.2 percent to 51.93 percent.

The second phase consisted of analysis of bio-chemical parameters in the blood of Type-I, Type-II and non diabetic subjects (n=60 consisting of 20 from each group) of age between 40-50 years. Antioxidant assay was done for enzymatic and non-enzymatic constituents. Non-enzymatic antioxidants like vitamin-A, vitamin–E, vitamin-C and enzymatic antioxidants like Super oxide dismutase and Catalyse were detected.

The cholesterol level is higher for the type-II diabetic (219.05 mg (SD6.425) patients compared to type-I and non diabetic subjects and it seems that the type-I diabetics control their cholesterol level better than the type-II diabetics. Significant difference between the male and female groups was found for TC, HDL and LDL levels with males showing a significant increase in the variable levels compared with the respective female group.
Among the three groups the non-diabetics showed better status for the values of vitamin A (type-I - 27.71(SD 6.54)ug/100ml, type-II - 27.41(SD 7.295)ug/100ml, non-diabetic- 39.79(SD 8.135)ug/100ml) and beta carotene (type-I - 55.42(SD 13.075)ug/100ml, type-II - 54.82(SD14.585)ug/100ml, non-diabetic- 79.58(SD 16.27)ug/100ml).

F- Test confirms that there is significant difference between the groups. Schiffee test found that the vitamin A and beta carotene level of type-I and type-II diabetic subjects are more similar than the non diabetic subjects. Hence the non-diabetics have a better status of serum vitamin A compared to the diabetic subjects. No significant difference was found between the male and female subjects.

The analysis of vitamin E showed negligible difference between the diabetics and the non-diabetics (type-I - 0.72(SD 0.145) mg percent, type-II - 0.75 (SD 0.155)mg percent, non diabetic- 0.75(SD 0.135) mg percent). F- test confirms that there is no significant difference between the three groups. Schiffee test found that the vitamin E level of type-I and type-II diabetic subjects are more similar to that of non diabetic subjects. Hence the serum vitamin E levels of type-I, type-II and non diabetic subjects do not vary considerably which may be due to the usage of considerable amount of oil in the South Indian diet.

The status of vitamin C was found lacking in both the type-I and type-II subjects. The non diabetic subjects (0.58 SD 0.11mg/100ml) have higher vitamin C level than the type-I (0.43 SD 0.075mg/100ml) and type-II (0.41 SD 0.075mg/100ml) diabetic subjects. F- test confirms that there is significant difference between the three groups. Schiffee test found that the blood sugar level of type-I and type-II diabetic subjects are more similar than the non diabetic subjects. Hence it could be inferred that diabetes may deplete the serum vitamin C status in the body. No significant difference was found in the mean vitamin E and vitamin C level of the male and female subjects.

Among the three groups the non-diabetics showed better status for the hemoglobin levels. Type-I diabetic subjects shows a hemoglobin level of 11.57(SD 0.95) mg/100ml; type-II 12.29(SD 0.79) mg/100ml
and non diabetic subjects with a higher value of 12.58 (SD 0.775) mg/100ml. The type-I male (12.50 SD 0.62 mg/100ml) subjects had higher levels of hemoglobin than their female (10.63 SD 1.28 mg/100ml) counterparts. The type-II diabetic subjects also showed same proportion among the males (12.90 SD 0.71 mg/100ml) and females (11.68 SD 0.87 mg/100ml). Since the biological requirement of males and females are different and the blood analysis also shows the difference between the male and female subjects.

The present study was designed to evaluate the activities of two antioxidant enzymes; superoxide dismutase and catalase in diabetic patients and to compare it with the values of the control group. The activities of two antioxidant enzymes; superoxide dismutase and catalase of patients suffering from type-I and type-II diabetes mellitus were significantly lower than those of control groups— the non diabetic subjects.

The absolute value and specific activity of Superoxide dismutase shows lower levels among the diabetic subjects and higher levels among the non-diabetics. The absolute activity of type-I (97.28 SD 7.79 U/ml) and type-II (103.25 SD 7.35 U/ml) diabetics were much below the reference value-122.4 U/ml; whereas the non-diabetic subjects (116.15 SD 7.55 U/ml) showed value much closer to the reference value. The specific activity of superoxide dismutase showed that the non diabetics have a higher specific activity of 923.95 SD 19.37 U/gHb even more than the reference value (reference value- 884.2 U/gHb) whereas the type-I and type-II subjects showed a lower activity of 842.05 SD 14.14 U/gHb and 839.80 SD 19.57 U/gHb respectively which is much below the reference value. Statistical analysis on f-test indicates that significant difference exists between the diabetic and non diabetic subjects. Schiff analysis to check the similarity between the groups also indicates that type-I and type-II diabetics are similar in their superoxide dismutase activity than compared to the non diabetics. Hence it can be inferred that the potential of the body to produce the enzymatic antioxidant—superoxide
dismutase is much lowered or progressively lowered with the onset among diabetics.

The absolute activity of Super oxide dismutase was found to have significant difference in gender wise analysis. Females showed lesser level of enzymatic antioxidant activity than male subjects. Statistical analysis on t–test was done to check the significance of the test results for the gender wise analysis. The male (104.09SD4.58 U/ml) and female (90.47SD11.00 U/ml) type-I subjects showed significant difference with t value3.615 and significance 0.002. The absolute activity of Super oxide dismutase for female subjects with type-II and non diabetic subjects were 97.57SD7.77 U/ml and 110.87SD6.41 U/ml respectively where as the corresponding value for the male subjects showed a higher activity value of 108.93SD6.93 U/ml (t value 3.452Sig0.003) and 121.44SD8.70 U/ml (t value 3.093 Sig 0.006) respectively.

The catalase activity of diabetic and non-diabetic subjects were analysed and found that the non-diabetic subjects have higher level of Catalase activity than the diabetic subjects. The absolute activity of catalase as per F-test (5.217Sig0.008) indicates significant difference between the diabetic and non diabetic subjects. The absolute activity of catalase is much lower for type-I (9.18 SD 0.96 k) and type-II (9.69 SD 1.13 k) subjects compared to the non diabetic (10.43 SD 1.225 k) subjects. But compared to the reference value (17.9 k) all the three groups show lower levels. On analyzing the specific activity of catalase it was found that the non-diabetic subjects have higher level of Catalase activity than the diabetic subjects. The specific activity of catalase for type-I (79.50SD 6.22 k/gHb) and type-II (78.88SD 6.59 k/gHb) subjects is much lower compared to the non diabetic (83.00(SD 8.78 k/gHb) subjects. But compared to the reference value (118.8 k/gHb) all the three groups show lower levels. Schiffee analysis to check the similarity between the groups also indicates that type-I and type-II diabetics are similar in their catalase-absolute and specific activity than the non diabetics. Hence it can be inferred that the
potential of the body to produce the enzymatic antioxidant– catalase is much lowered or progressively lowered with diabetes.

The absolute activity of catalase was found to have significant difference in gender wise analysis. Females showed lesser level of enzymatic antioxidant activity than male subjects among the type-I subjects. Statistical analysis on t–test was done to check the significance of the test results for the gender wise analysis, The absolute activity of catalase for the male (9.95SD0.88k) and female (8.42SD1.04U/ml) type-I subjects showed significant difference with t value 3.554 and significance 0.002. Females were having a lesser activity for catalase. The specific activity of catalase shows that type-II diabetic females (81.45SD8.1 k/gHb) have higher activity level than the males (76.31SD4.37 k/gHb). Hence it can be inferred that type-I Females have lesser level of enzymatic antioxidant activity of catalase than male subjects, while type-II females have higher level of enzymatic antioxidant activity of catalase than male subjects.

In general the antioxidant status was found depleted in both the diabetic groups. Among the diabetic subjects, both the type-I and type-II subjects showed negligible difference in the serum vitamin A, beta carotene, vitamin E, superoxide dismutase and catalase content. Analysis of serum vitamin C indicates increase in level among the type-II diabetics than in type-I diabetics. The diabetic subjects have lesser antioxidant status compared to non diabetics which may be due to net retardation of health.

Decrease of Endogenous (Enzymatic) Antioxidants and Exogenous (Non-Enzymatic) Antioxidants monitored in Type-I and Type-II diabetes demonstrates that protective system against oxidative stress is impaired when compared to non-diabetic counterparts. There is every reason to state that Diabetes and its complications are possible to alter the antioxidant protection system and will remain as a threat to public health in this century and beyond. Endogenous Antioxidants and Exogenous Antioxidants level may be considered as functional parameter for monitoring diabetes.
In the third phase, for intensive supplementation study newly diagnosed diabetic patients of age between 40 and 50 were selected as micro samples (n=20). The subjects were given dietary counseling, diabetic and nutritional awareness. The dietary antioxidant status was assessed through one day weighment method. All the subjects were supplemented with spirulina biscuits and lime juice for one month. Blood was analysed before and after the supplementation period for its sugar, cholesterol, hemoglobin and antioxidant content.

Nutrition counseling is an ongoing process in which a dietitian works with an individual to assess his or her usual dietary intake and identify areas where change is needed. After the education programme the knowledge was assessed through an awareness questionnaire and the rate of awareness was measured. To understand the effect of any nutrition education programme, its evaluation after a specific period is essential. It was found that the subjects have migrated from the poor and average zone to the good and excellent zone, which indicates the effectiveness of individual counseling. It could be an inexpensive mode of managing diabetes. Ignorance is the cause for improper management of many of the disease condition hence the diabetic subjects must be given proper guidance and counseling.

The percentage of subjects with poor awareness level decreased from 42.69 percent to 18.46 percent. The subjects migrated from poor and average zone to good and excellent zone. Excellent awareness score above 90 percent was shown by 15.13 percent of the subjects. In the good awareness zone the score rose from 18.27 percent to 40.57 percent.

The invitro analysis of the antioxidant status in the body by measuring the daily food intake was done before and after counseling. Cooked food was weighed using an accurate balance in the morning, noon and evening before intake. It is then converted to raw portion size and the nutrient intake was calculated. Additional food consumed by the subjects like food brought from shops, sweets and other food accepted from friends and relatives were also noted in details before computing the nutritive value. Students't’ test indicate that there is
significant difference in the dietary antioxidant status of the newly diagnosed diabetic subjects.

The carbohydrate in the diet for meals diabetic subjects was 339.54g before counseling and after counseling it reduced to 311.25g. For female subjects the carbohydrate amounts to 293.83 g and 285.73 g after counseling. A high protein diet offering 20 percent of the calories is found efficient in the management of diabetes, 67.31g of protein was consumed by the subjects before counseling and after counseling it increased to 71.62 grams among the males and from 54.76mg to 69.43g for females. The increase in the vitamin C, beta carotene and iron was significant, whereas change in selenium; copper and zinc are not prominent. The intake of protein is found adequate.

A supplement was formulated with the idea of incorporating all the nutrients needed for diabetic subjects, especially antioxidants. Components which are essentially required are carbohydrates, proteins vitamins and minerals, and fat in a reduced proportion. When these ingredients are used together in suitable proportions they form a complete meal. The supplement was formulated as a snack for the newly diagnosed diabetic subjects. Ingredients selected for formulating the spirulina biscuit, contains whole wheat flour as the staple carbohydrate rather than Maida or white flour due to its fiber content, spirulina the proteins supplement was selected with the aim of having 100% digestibility arising from a vegetarian source, it is also an ore of antioxidant vitamins and minerals. The energy supplement was selected from a variety of oils from different oil seeds, like ground nuts, palm and Safflower seeds; to ensure sufficient essential fatty acid content. Safflower oil, Olive oil and Ground nut oil was used in 1:1:1 ratio. No sugar was added as the supplement was aimed at diabetic subjects. Incorporation of unsaturated fats (like Olive oil, Safflower oil, and Groundnut oil) instead of saturated fats (like dalda, ghee or butter) prevents the increase of blood cholesterol even if consumed daily. The ratio of different oils used was maintained as 1:1:1, so that the saturated and unsaturated fats ratio in the body could be maintained rather than using single oil.
The recipe was formulated in such a way that it contained 40 percent of carbohydrates, 20 percent of protein, 10 percent of fat, 20 percent of vitamins and 10 percent of minerals. For the standardization of the recipe, three variations were done on the basis of pre-determined allotment of nutrients. In order to identify the acceptable proportion of ingredients in the supplement, the amount of basic ingredients like wheat flour, Garam masala and salt were kept constant where as the proportion of spirulina was altered. Increasing and decreasing the amount of spirulina enabled to find out the maximum accepted level of spirulina that could be used for supplementation. Variation was brought about by changing the amount of spirulina where as the amount of basic ingredients were kept constant. The variations were named as variation one (V₁), variation two (V₂) and variation three (V₃) contains 40g, 60g and 80g, of spirulina respectively.

Successive trails of the recipe adopting the changes recommended from the previous trials were carried out until the product was satisfactory in all aspects. The total yield of biscuits obtained after baking for the variations V₁, V₂, and V₃ were 407.5g, 427.5g and 447.5g respectively. The standardized product in variation one (V₁) contained 27 biscuits, in variation two (V₂) 29 biscuits and variation three (V₃) contained 30 biscuits each weighing approximately 15 grams.

The mean weight of spirulina per biscuit was computed and found that 2.65g of spirulina was present in variation one (V₁), 4.07g in variation two (V₂) and 5.36g of spirulina was present in variation three (V₃). Hence the amount of spirulina in V₁, V₂, and V₃ differed in the ratio 3:4:5.

Quality is the ultimate criterion of the desirability of any food product. The overall quality of a food depends on sensory qualities, nutritional significance and other hidden attributes. Food quality was evaluated by both sensory and objective methods. The quality and acceptability of the spirulina biscuits were assessed with special reference to organoleptic qualities with the help of sense organs,
storage stability by microbial assay and nutritional significance of the product by computing the nutritive value.

A score card was used for the organeoleptic evaluation of the spirulina biscuits. Appearance, Colour Doneness, Flavour, Texture and Taste were the main parameters assessed. Acceptability of food means the overall acceptability of all the parameters like appearance, colour, flavor, doneness, taste and texture. Variation one \( (V_1) \) containing 2.65g of spirulina per biscuit (total score 529.67 and mean score 75.67) scored the maximum compared to \( V_2 \) (total score 483.00 and mean score 69.00) and \( V_3 \) (total score 401.33 and mean score 57.33). Hence variation one was selected for supplementation as per the evaluation results of the technical experts.

Every time when food is eaten a judgment is made. The acceptance of the public is of prime importance especially the diabetic subjects as they decide the existence of a diabetic biscuit in the commercial market. Common man is capable of judging the quality of the product. On comparing the total scores and mean obtained between groups obtained from the public it was found that variation one \( (V_1) \) containing 2.65g of spirulina per biscuit scored the maximum. Hence as per the interest of the public and the expert panel members variation one \( (V_1) \) was selected for all further analysis.

The developed diabetic supplement was compared with popular commercially available biscuits for its nutritional significance and cost. The developed diabetic supplement spirulina biscuit was compared with four popular commercially available biscuits designated as Brand A, Brand B, Brand C and Brand D respectively. It was found that the commercially available biscuits were saturated with fat and contained more calories per 100g where as the developed spirulina biscuit was rich in protein and other antioxidants.

The Protein content is very high in spirulina biscuit (13.98 g/100g) compared to others (Brand A-6.44g/100g, Brand B-10 g/100g, Brand C-8.5 g/100g, Brand D-7.9 g/100g). Fat content was found extremely lesser in the supplement (3.78g/100g) compared to other brands (Brand A-24.16g/100g, Brand B-15.5g/100g, Brand C-
22.0g/100g Brand D-15.5g/100g). On computing the Total Monounsaturates (80.97 g/100g) and Total Poly Unsaturates (73.15g/100g) which provide good cholesterol to the body is high in spirulina biscuit compared to the commercial brands. Minerals were found higher in the supplement (2.46g/100g) where as it wasn’t revealed in any one of the commercial brands. Energy value of the supplement (459.73kcal/100g) was almost at par with the commercial brands (Brand A-505.36 Kcal/100g, Brand B-456 Kcal/100g, Brand C-470 Kcal/ 100g, and Brand D-433 Kcal/100 g). But the amount of Carbohydrates was found lesser in the supplement (48.54g/100g) which benefits the diabetic subjects on supplementation.

The quantity of antioxidant vitamins in the spirulina biscuit was found extremely high (Vitamin A/βcarotene-15938.10µg/100g, Vitamin E/α Tocopherol-0.88IU/100g) which makes it suitable for supplementation, whereas it wasn’t mentioned or significant in any of the commercial brands. The amount of calcium (121.09mg/100g), Phosphorus (321.09mg/100g), Iron (16.60mg/100g) and Selenium (1.77µg/100g), was found higher in spirulina biscuit compared to any other commercial biscuits. Pigments like Phycocyanin (Blue) (1326.53mg/100g), Chlorophyll (Green) (101.70mg/100g) and Carotenoids (Orange) (32.72mg/100g) makes the supplement novel and nutritious. The fibre content in spirulina biscuit is 85.03g/100g, which cannot be attained from any other brands though Brand A contains Polyols (22.21 g/100g); Brand B, Brand C or Brand D do not possess significant amount of dietary fibre. Addition of sugar was yet another factor noticed in Brand B (3 g/100g) and Brand C (18.6 g/100g) where as no sugar was added to the spirulina biscuit as it was strictly meant for diabetic subjects.

The cost of the Supplement was computed according to the existing market price of each ingredient used. The cost of each ingredient in Indian Rupees was worked out by dividing total cost of the product by Edible Portion Weight (EPW). The cost of 100g of the developed product was compared with cost of 100g of four commercially available biscuits designated as Brands A, B, C and D. It
was found that three brands (Brand B, Brand C and Brand D) made for diabetic patients were of Rs.14/100g each where as Brand A costs Rs.38/100g. The cost of the developed supplement spirulina biscuit was Rs 15/100g with over head taxes fixed at 20 percent. Compared to the nutritional significance and therapeutic value, the cost of the spirulina biscuit is negligible.

Food is prone to microbial decomposition because they are rich in nutrients that support the growth of microbes. Storage stability of a product depends on the ability of the supplement to remain edible during the storage period without bacterial or fungal invasion and without change in colour, texture, flavour, odour, appearance and taste. For testing the shelf life of the developed supplement it was packed in poly propylene covers and was stored in an air tight container at room temperature for a period of six months. After the storage period the total microbial counts i.e. both the number of bacterial and fungal colonies was determined.

After an incubation period of 48 hours on a nutrient agar medium 40,000 number of Bacterial Colonies were found per gram of the spirulina biscuit. After an incubation period of 72 hours on a Saboaurd Dextrose Agar (SDA) medium 10,000 number of Fungal Colonies were found per gram of the spirulina biscuit. The Bureau of Indian Standards (BIS) specified a maximum microbial count (Fungal and Bacterial count) of 50,000 per gram for supplements like biscuits. Hence it was found that there was no significant microbial growth in the supplement and that the biscuits have good storage stability since the microbial count was well within the specified limits.

Organoleptic quality of the selected supplement spirulina biscuits ($V_1$) was again assessed after six months of storage based on the preferences of technical experts. It is necessary to re-assess the organoleptic qualities on the development of new food products like spirulina biscuits. The qualities which were assessed earlier like appearance, colour, doneness, flavour, texture and taste were the main criterion that was determined to check the acceptability of the product subjected to sensory evaluation.
The Standard Deviation and Co-efficient of Variation based on the total score obtained by the acceptability test before and after storing for six months found that the mean score of the supplement was 75.67 percent and after six months it was 73.84 percent. There was only a negligible change in the scores before and after six months.

On account of the least value for the Co-efficient of Variation the supplement showed greatest consistency in the scores based on the six factors considered. Irrespective of the factors tested the variation in scores before and after six months is least in the supplement. Statistical analysis on t test shows that there is no significant difference between the scores before and after storage at 5% level of significance. Thus it was inferred that the spirulina biscuits if properly stored in a moisture free environment the shelf life is assured for six months having microbial and fungal counts within the limits.

Standardized spirulina biscuits were supplemented to the twenty (n=20) newly diagnosed diabetic subjects. The subjects were requested to consume spirulina biscuits and drink of 15ml lime juice as spirulina was found lacking in vitamin C. Each subject was given a prescribed calorie intake according to their BMI, and was requested not to deviate from the prescribed calorie intake from one week prior to the supplementation phase and to continue it. Spirulina biscuits and lime juice were supplemented for a period of one month (30 days). To assess the change in antioxidant status initial blood samples were collected for detailed analysis. After the supplementation period of one month blood samples were again collected and were estimated for glucose, lipid profile, hemoglobin level, activities of enzymatic antioxidants like Cu-Zn super oxide dismutase and catalase and non enzymatic antioxidants like Vitamin A, Vitamin E and Vitamin C.

Analysis of Blood Sugar level revealed that significant difference exists in values before and after supplementation. The initial Fasting Blood Sugar level was 115.25 mg/dl(±13.12), which decreased to 94.90 mg/dl(±8.61) after spirulina biscuit supplementation. Post-Prandial Blood Sugar level also reveals the same progress, were the
initial level of 189.10 mg/dl(SD±60.41), declined to 129.25mg/dl(SD±20.95) after one month of supplementation. Statistical analysis on t test shows that there is significant difference in the initial and final values of Fasting and Post-Prandial Blood Sugar level the newly diagnosed type-II subjects.

the blood sugar level of male and female type-II diabetic subjects before and after spirulina biscuit supplementation shows that the mean Fasting Blood Sugar level of male diabetic subjects reduced from 115.50(SD15.59) mg/dl to 93.70(SD8.69) mg/dl with t value-7.474 (Sig 0.000) and the Post-Prandial Blood Sugar proportionally decreased from 187.90(SD53.65) mg/dl to 136.70(SD19.08) mg/dl with t value 4.339 (Sig 0.002) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the Fasting Blood Sugar level reduced from 115.00(SD10.97) mg/dl to 96.10(SD8.81) mg/dl with t value-10.041(Sig 0.000) and the Post-Prandial Blood Sugar decreased from 190.30(SD69.45) mg/dl to 121.80(SD 20.95)mg/dl with t value 3.990 (Sig 0.003) showing statistical significance in supplementation.

On supplementing spirulina biscuit the total cholesterol level decreased from 219.05(SD±36.43) mg/dl, to 188.15(SD±29.84) mg/dl and Low Density Lipoproteins (LDL) decreased from 153.40 mg/dl (SD±5.49) to 138.05 mg/dl (SD±7.92). The level of High Density Lipoproteins (HDL) showed remarkable progress after the spirulina supplementation, which increased from 40.75 mg/dl (SD±4.27) to 48.50 mg/dl (SD±4.85). Statistical analysis on t test shows that there is significant difference in the initial and final values of Total Cholesterol level, Low Density Lipoproteins levels (LDL) and High Density Lipoproteins level (HDL) of the newly diagnosed type-II subjects.

The mean values of Total Cholesterol, HDL–cholesterol and LDL–cholesterol levels of male and female diabetic subjects shows significant improvement in the lipid profile. For the male subjects the Total Cholesterol reduced from 225.90 (SD41.15)mg/dl to 193.90(SD31.88)mg/dl with t value- 8.256 (Sig 0.000) and the LDL–cholesterol levels from 153.20 (SD5.33)mg/dl to 136.90(SD7.20)mg/dl
with $t$ value 9.444 (Sig 0.000); while the HDL–cholesterol showed remarkable increase in the mean values increasing from 42.50 (SD4.35) mg/dl to 50.20 (SD4.87) mg/dl with $t$ value -6.454 (Sig 0.002) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the Total Cholesterol reduced from 212.20 (SD 31.70)mg/dl to 182.40 (SD 28.10)mg/dl with $t$ value-8.785 (Sig 0.000) along with a proportional reduction in the LDL–cholesterol levels from 153.60 (SD5.93)mg/dl to 139.20(SD8.82)mg/dl with $t$ value -8.308 (Sig 0.000); while the HDL–cholesterol showed remarkable increase in the mean values increasing from 39.00 (SD 3.56) mg/dl to 46.80 (SD 4.42) mg/dl with $t$ value -12.766 (Sig 0.000) showing statistical significance in supplementation.

The initial hemoglobin level was lower (11.29±0.99SD mg/100ml) than the final values which may be due to the formation of glycosylated hemoglobin. The increase in the level of hemoglobin (12.93±1.03SD mg/100ml) after spirulina biscuit supplementation may have been due to the decreased level of blood glucose that would automatically lead to a decrease in glycosylated hemoglobin. Another reason might be that spirulina, which is a rich source of iron, contributed to the elevated levels of hemoglobin Statistical analysis on t test shows that there is significant difference in the initial and final values of hemoglobin level. It can be inferred from the study that diabetic patients tend to have lesser hemoglobin concentration which can be compacted through a food based rather than a drug based approach.

The mean Hemoglobin level of male diabetic subjects increased from 12.90(SD0.71) mg/100ml to 13.66(SD0.78) mg/100ml with $t$ value -10.585(Sig 0.000) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the Hemoglobin level increased from 11.68(SD 0.87)mg/dl to 12.19(SD0.65)mg/dl with $t$ value -5.667 (Sig 0.000) showing statistical significance in supplementation.
Analysis of blood on antioxidant status, after the completion of supplementation showed considerable increase in the non-enzymatic antioxidants like Vitamin A, Vitamin E and Vitamin C.

Serum vitamin A increased from 27.41±7.62SD µg/100ml to 37.99±7.84SD µg/100ml and serum βCarotene increased from 54.82±15.24SD µg/100ml to 90.12±19.78 SD µg/100ml after 30 days supplementation with spirulina biscuit. Statistical analysis on t test shows that there is significant difference in the initial and final values of Serum vitamin A and serum βCarotene level of the newly diagnosed type-II diabetic subjects.

The mean Vitamin A concentration of male diabetic subjects increased from 25.32(SD5.50) ug/100ml to 35.48(SD5.23) ug/100ml with t value -16.642 (Sig 0.000) and the Beta Carotene level proportionally increased from 50.64(SD10.99) ug/100ml to 84.71(SD13.28)ug/100ml with t value -17.240 (Sig 0.000) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the mean Vitamin A concentration increased from 29.50(SD9.09)ug/100ml to 40.50(SD9.40)ug/100ml with t value -14.581 (Sig 0.000) and the Beta Carotene level proportionally increased from 59.00(SD18.18)ug/100ml to 95.53(SD24.18)ug/100ml with t value -16.238 (Sig 0.000) showing statistical significance in supplementation.

After supplementation of spirulina biscuits serum Vitamin E increased from 0.75±0.16SD mg percent to 0.91±0.11SD mg percent. Statistical analysis on t test shows that there is significant difference in the initial and final values of Serum Vitamin E level of the newly diagnosed type-II diabetic subjects. The mean Vitamin E concentration of male diabetic subjects increased from 0.71(SD0.11) mg percent to 0.89(SD0.09)mg percent with t value -10.816 (Sig 0.000) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the mean Vitamin E concentration increased from 0.78(SD0.20)mg percent to 0.94(SD0.14)mg percent with t value -6.556 (Sig 0.000) showing statistical significance in supplementation.
On supplementation with 15ml of lime juice and spirulina biscuit, serum vitamin C levels increased from 0.41±0.08SD mg/100ml to 0.59±0.09SD mg/100ml. Statistical analysis on t test also shows that there is significant difference in the initial and final values of Serum Vitamin C level of the newly diagnosed type-II diabetic subjects. Normal values for human plasma or serum is 0.4 to 1.5 mg/100 ml. The mean Vitamin C concentration of male diabetic subjects increased from 0.41(SD0.06)mg/100ml to 0.68(SD0.06)mg/100ml with t value -70.429 (Sig 0.000) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the mean Vitamin C concentration increased from 0.40(SD0.09)mg/100ml to 0.51(SD0.11)mg/100ml with t value -36.375 (Sig 0.000) showing statistical significance in supplementation.

The effect of supplementing spirulina biscuit on the serum levels of Superoxide Dismutase (SOD) and Catalase were analysed.

The absolute activity (U/ml) of the enzymatic antioxidant Superoxide dismutase increased from 103.25±9.23SD U/ml to 112.93±9.58SD U/ml and the specific activity (U/gHb) increased from 839.80±19.60SD U/gHb to 873.60±18.64SD U/gHb and after 30 days of spirulina and lime juice supplementation. Statistical analysis on t test shows that there is significant difference in the initial and final values of specific activities and absolute activities of Serum Superoxide dismutase levels of the newly diagnosed type-II diabetic subjects.

SOD units were obtained from standard curve using percentage inhibition of the sample. SOD units/ml of whole blood is absolute activity and was converted to SOD units/gram of hemoglobin which is the specific activity. The absolute activity of Super oxide dismutase for male diabetic subjects increased from 108.93(SD6.93) U/ml to 118.74(SD8.44)U/ml with t value -14.392 (Sig 0.000) and the specific activity increased from 844.30 (SD19.89)U/gHb to 868.70(SD14.45)U/gHb with t value -6.172 (Sig 0.000) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the absolute activity of Super oxide dismutase increased from 97.57(SD7.77)U/ml to
107.12(SD6.91)U/ml with t value -12.340 (Sig 0.000) and the specific activity increased from 835.30(SD19.25)U/gHb to 878.50(SD21.71)U/gHb with t value -12.098 (Sig 0.000) showing statistical significance in supplementation. It was also found that as the blood sugar increases the corresponding superoxide dismutase level decreases.

The absolute activity (k) of the enzymatic antioxidant Catalase increased from 9.69±1.13SD k to 11.62±1.02SD k and the specific activity (k/gHb) of Catalase increased from 78.88±7.26SD k/gHb to 90.03±5.78SD k/gHb after spirulina biscuit supplementation for 30 days. Statistical analysis on t test shows that there is significant difference in the initial and final values of specific activities and absolute activities of Serum Catalase levels of the newly diagnosed type-II diabetic subjects.

The absolute activity of Catalase for male diabetic subjects increased from 9.86(SD0.94)k to 11.85(SD1.21)k with t value -14.843 (Sig 0.000) and the specific activity increased from 76.31(SD4.37) k/gHb to 86.66(SD5.62) k/gHb with t value -11.409 (Sig 0.000) showing statistical significance in supplementation. The female subjects also showed similar response on supplementation where the absolute activity of Catalase increased from 9.52(SD1.32)k to 11.39(SD0.79)k with t value -5.918 (Sig 0.000) and the specific activity increased from 81.45(SD8.81)k/gHb to 93.40(SD3.72)k/gHb with t value -4.824 (Sig 0.001) showing statistical significance in supplementation. It was also found that as the blood sugar increases the corresponding catalase level decreases. The findings suggest that raised redcell glucose may exhaust red cell catalase. Low level of red cell catalase in diabetics may be a risk factor for the complications of diabetes mellitus.

**CONCLUSION**

On analyzing the socio-economic, dietary, life style, health and clinical status of diabetic patients it can be concluded from the present study that diabetes which is hindering the peaceful life of our
population is as a result of many factors like genetic inheritance, ageing, change in diet and life style pattern. Cultural transition from a producer state to a consumer state might have contributed to obesity and higher waist-hip ratio. Proper attention must be taken to manage the situation from becoming worse as a huge majority of male and female diabetic subjects are at moderate to high risk of obesity. Lack of daily exercise can also add to the problems as it can be a causative factor for the increase of the huge diabetic population in the country. Though we can be proud of being well educated compared to other states, only half are aware of the significance of daily exercise. Knowledge, Apperception and Practice are different, as among those who are aware, those practicing daily exercise was feeble. Hence nationwide Diabetes Prevention Programs with a network of community-based, group lifestyle intervention for overweight or obese people at high risk of developing type-II diabetes need to be started with immediate effect.

The sex-wise distribution of subjects with Diabetes Mellitus showed that the proportion of males and females are almost equal. This shows the increasing prevalence of women diabetic patients in India. High prevalence of diabetics was found among the city dwellers. The age of subjects approaching Type-II diabetes was found reducing; hence for a healthy adulthood everyone should be conscious to have regular health checkups after the age of thirty eight. It is easier to bring change among the educated mass and hence web-sites offering group lifestyle intervention programmes should be started, with plans to expand and reach to all sectors of the Indian population in local languages.

Though the subjects know that intake of stimulants are injurious to health they drink alcohol, smoke and few chew tobacco. Constant use of these stimulants can increase the free radical production in the body to an uncontrollable extend, which aggravates the malady. The most commonly found diabetic complications were retinopathy and neuropathy. Multiple complications in diabetic patients need intensive care and proper guidance.
Tension, stress and strain, is the major factor that tampers the mental health in majority of the subjects which leads to sleeplessness and delayed mental programming and to depression in the critical stage. Non-vegetarians were found to be more in number than the vegetarians. Parboiled rice and wheat flour are consumed for more than twenty five days a month while pulses and legumes are consumed for less than five days a month. Milk which is an integral part of the daily routine is consumed almost daily. Fish and sea foods were consumed for more than twenty five days a month. Compared to meat, egg was more commonly consumed and Beef or Chicken was preferred more to Mutton and pork.

Ripe plantain is the only fruit consumed for more than twenty five days a month by the subjects. Drumstick leaves and amaranthus are consumed more often compared to araikeera, and agathi. Coconut oil was found to the most commonly used oils, Coconut which is the taste maker of almost all Kerala dishes is consumed daily by cent percent subjects, The neutraceutical product Spirullina was totally an alien for all the subjects. Not even a single subject was under the practice of consuming the product.

The analysis of 24 hour recall method found that type-I patients have a better outlook in dietary regimen compared to their type-II counterparts as the calorie, carbohydrates, proteins, and fat intake is lesser than the type-II patients. Diabetic subjects have basic awareness on the symptoms and complications of diabetes mellitus

The antioxidant status was found depleted in both the type-I and type-II diabetic groups of 40-50 years of age. Decrease of Endogenous (Enzymatic) Antioxidants and Exogenous (Non-Enzymatic) Antioxidants monitored in Type-I and Type-II diabetes demonstrates that antioxidant status - the protective system against oxidative stress is impaired when compared to non-diabetic counterparts. Both the type-I and type-II subjects showed negligible difference in the serum vitamin A, beta carotene, vitamin E, superoxide dismutase and catalase content. Analysis of serum vitamin C indicates increase in level among the type-II diabetics than in type-I diabetics. The diabetic
subjects have lesser antioxidant status compared to non diabetics which may be due to net retardation of health. Gender difference was found to have significant role among the subjects. Female subjects showed lesser activity for the enzymatic antioxidants superoxide dismutase and catalase; whereas gender difference was not significant in vitamin C levels.

Hence there is every reason to state that Diabetes and its complications are possible to alter the antioxidant protection system and will remain as a threat to public health in this century and beyond. Endogenous Antioxidants and Exogenous Antioxidants level may be considered as functional indicator for monitoring type-I and type-II diabetes.

Traditional therapies always rely on the use of natural products and have been the source of information for the discovery of many drugs we have today. The antioxidant potential many of the natural products are hidden as there are only very less number of intensive researches in the area. Spirulina biscuits and lime juice supplementation revealed beneficial effects before and after supplementation; as it was also found that the supplements have hypoglycemic and hypocholesterolemic effect with natural antioxidant potential which helps the diabetics to have control on blood glucose levels and also to deter the complications. Spirulina which is a good source of β-carotene, vitamin E and pigments like phycocyanine, other carotenoids on supplementation improved the serum carotenoids, vitamin E, vitamin A and vitamin C levels of the newly diagnosed diabetic subjects. The red blood cell superoxide dismutase (Cu/Zn-SOD) and CAT enzyme activities were found to have significant increase on supplementing with spirulina.

To our knowledge, this is the first report to document the finding on spirulina biscuit and lime juice supplementation.

The supplement spirulina biscuit was made from a special composition of garam masala which includes nine different spices like Cinnamon, Pepper, Cloves, Nutmeg, Fennel, Cumin seed, Cardamom, Star Anise and Mace providing 45g per day. On detailed literature
analysis it was found that spices also contain potential antioxidants that are capable of increasing the antioxidant status which might have contributed in maintain normoglycaemia and increase in antioxidant status.

We have inferred from the study that the special combination of oils used in the preparation of the biscuit is also significant in providing the essential fatty acids and maintaining the HDL, LDL and total cholesterol levels scientifically. Safflower oil, Virgin Olive oil and Groundnut oil contains mono unsatrates and poly unsaturates. These oils are an ore of different antioxidants having special health benefits. This might have also contributed to the increase in antioxidant status, hypoglycemic and hypocholesterolemic effect on supplementation.

Growing consumer interest in natural food ingredient and their tendency to avoid synthetic products which are unsafe will be the driving force in the usage of supplements like spirulina biscuit, containing a special combination of antioxidants.

The primary need of a diabetic patient is to attain and sustain normo-glycemia. Their potential problems are largely the complications that could develop as a result of poor management of the disorder. Management and treatment of diabetes is difficult due to lack of awareness, lack of education and health care facilities. It is important that together with supplementation with spirulina biscuits, nutrition education should be imparted to the diabetic patients as well as their family members and upcoming generation to emphasize on the consumption of healthy diet.

It appears conceivable that the beneficial effects of antioxidants could be enhanced by the presence of a variety of antioxidants, which are present in the spices, lime juice and spirulina. More over the supplements like spirulina is an appetite suppressor which might have added to the reduction in cholesterol. The increase in antioxidant status of the diabetic subjects therefore represents a steady state that would be maintained if spirulina biscuit and lime juice supplementation were extended indefinitely. No toxicity or evidence of other unwanted pharmacological effects of Spirulina was noted during supplementation.
This study met its objectives of establishing that food supplementation have a positive impact of on the antioxidant status of diabetic patients. Spirulina biscuit and lime juice supplementation is a safe and effective way of decreasing oxidative stress in middle aged type-II diabetic human subjects. The dosage defined (3g spirulina, 15ml lime juice, and 45g spices per day) seems well positioned for safety and efficacy.

Form the study; we have come to a conclusion that the natural antioxidant potential of Spirulina biscuits and lime juice helps the diabetics to have control on blood glucose levels and also to deter the complications due to its hypoglycemic and hypocholesterolemic effect. The health benefits of spirulina, spices and lime juice, are overwhelming in different areas for its potential therapeutic application. Currently, increased cost of health care has become a driving force in the shift towards interest in wellness, self-care, alternative medicine and diet management.

It is hoped that a careful evaluation of the results of the studies summarized above will provide a guide to future research and a basis for current therapeutic use of the supplement developed. Spirulina biscuit and lime juice supplementation can be used to make up for the diabetic stress, resulting in better nutritional status which further improved the antioxidant status of the subjects. India being the diabetic capital, the Central and/or State Government should formulate some policy of supplying spirulina biscuits free of cost to those needy sections of the society- to reduce the heavy expense on health of the population and to lessen the complications of life style diseases.

Since the supplementation of spirulina biscuit was found effective certain recipes were developed for the daily use of even the layman so that daily consumption may be assured. The recipes selected for supplementing spirulina were in such a way that it is the most commonly consumed item and easy to make. Hence recipes for breakfast, lunch and dinner were selected and standardized. Since the study is oriented for diabetic subjects the recipes selected were non sugar items for daily use without additional time consumption. Economical and locally available recipes were selected to incorporate
spirulina. The recipes were evolved on the basis of standard recipes from South Indian Region based on the standardized recipes from Indian Recipes compiled by the National Institute of Nutrition and ICMR.

There is a need to continue to explore the relationship between spirulina, antioxidants, free radicals, oxidative stress and diabetes to elucidate the mechanisms of control and development of diabetic complications. It is necessary to plan more coherent studies on the subject in the future, in order to explain the pathophysiology of the antioxidant mechanism in more detail.

SUGGESTIONS AND RECOMMENDATIONS

India is at present accredited with the certificate of being the diabetic capital of the world. Increasing prevalence of diabetes highlights an urgent need for preventive action to avert a public health catastrophe in India. Patients must mandatorily stick on to regular physical activities or exercise and also must proceed with dietary restrictions. People who are at a high risk of developing diabetes like aged and those with genetic susceptibility should begin to control their food and activities at a very early stage of life since the onset of diabetes is getting earlier now a days.

Measures must be taken to improve awareness among both urban and rural population and patient counseling and diabetic education programs can be conducted. Mass communication media could play an essential role in creating awareness among the public about the disease. Our ultimate aim should be to recognize the socio-economic burden of this slow and silent killer and immediately implement preventive strategies. Antioxidant potential products like spirulina must be included in the dietary regimen to have a better balance of the body’s defense mechanism against the oxidative stress and free radical production.
1. Basics of nutrition and dietetics must be imparted from schools since proper dietary management is essential from early stage of human life to sustain health and wellbeing.

2. The age of subjects approaching Type-II diabetes was found reducing; hence for a healthy adulthood everyone should be conscious to have regular health checkups after the age of thirty eight.

3. Nationwide Diabetes Prevention Programs with a network of community-based, group lifestyle interventions, Diabetes and Dietary awareness programmes must be initiated; especially in Schools, Colleges, Self Help Groups, NGO’s, Residents Associations and other agencies with the guidance of medical practitioner.

4. Web-sites offering group lifestyle intervention programmes should be started, with plans to expand and reach to all sectors of the Indian population in local languages.

5. Dietary antioxidants play a major role in the health status of the diabetic people, and hence natural products like spirulina having antioxidant potential may be consumed. So it is recommended that the management protocol for diabetes patients should include antioxidant supplementation.

6. Future research should focus on an evaluation of which nutrients may help to prevent the onset and the progression of diabetes and related complications.

7. India being the diabetic capital, the Central Government should formulate some policy of supplying spirulina free of cost to those sections of the society to:

   • reduce the heavy expense on health of the Indian population;
   • lessen the complications of life style diseases and
   • improve health status of the citizens of the diabetic world