 Ethno-Med, 3(2): 119-126 (2009)

# Effect of Spirulina Supplementation on the Nutrient Adequacy and Health Status of Non-Insulin-Dependent Diabetes Mellitus (NIDDM) Male Subjects

**Kamalpreet Kaur, Rajbir Sachdeva and Anita Kochhar**

*Department of Food and Nutrition, College of Home Science, Punjab Agricultural University, Ludhiana 141 004, Punjab, India*

**KEYWORDS** Spirulina. Diabetes. Nutrients. Haematological Profile

**ABSTRACT** Sixty male diabetic subjects (40 years) of middle income group were selected from Punjab Agricultural University, Hospital, Ludhiana and divided equally into three groups viz. $E_1$, $E_2$ and C. Spirulina supplementation was given daily in the form of SUNOVA capsules with two capsules (lg) and four capsules (2g) to $E_1$ & $E_2$ group respectively for a period of two months and C group was not given any supplementation. The impact of spirulina supplimentation was studied individually on nutrient intake and haematological profile of the subjects before and after the study. It was observed that mean carbohydrate and protien intake decerased significantly ($P<0.01$) in group $E_2$ while non significantly in Group $E_1$ and C. It was observed that there was an improvement in the haematological profile of the subjects of $E_1$ and $E_2$ because spirulina contained highly available form of iron, calcium, magnesium, copper, vitamin $B_{12}$, folic acid and vitamin $B_6$ which are essential for haemopoiesis. It is suggested that 2g of spirulina supplementation can improve iron status of NIDDM subjects.

## INTRODUCTION

Diabetes is a single most important metabolic disease which can affect nearly every organ system in the body. The reasons for this escalation are due to changes in lifestyle; people living longer than before (ageing) and low birth weight could lead to diabetes during adulthood. (Pradeepa et al. 2002). Diabetes is recognized to be common in Asian Indians. The number of people with diabetes in the world is expected to double between the year 2000 and 2030. The greatest absolute increase in the number of people with diabetes will be in India (Wild et al. 2004). Diabetes mellitus, a complex metabolic disorder, has been associated with diet for centuries. Diabetic diet need not be a complete deviation from normal healthy diet Most of the carbohydrate is to be in form of complex carbohydrate with high fibre content and low glycemic index.

Spirulina called a superfood, a microalgae which is gaining popularity in recent years as a major food supplement and its nutrient profile is more potent than any other food, plant, grain or herb. The nutrients and phytonutrients make spirulina a whole food alternative to isolated vitamin supplements. It has been found to be a rich natural source of protein, vitamin $B_{12}$ of plant origin and contains a spectrum of natural antioxidant like β-carotene, vitamin $B_1$, $B_5$, $B_6$, vitamin E, iron, zinc, manganese, copper and selenium which helps in improving general health and vigour. The pigment phycocyanin present in spirulina helps to strengthen the body's defence system (Kauser and Parveen 1999).

So the present investigation was undertaken to see the effect of spirulina supplementation on the nutrient adequacy and health status of NIDDM male subjects.

## MATERIALS AND METHODS

***Selection of the Subjects:*** A sample of sixty male subjects aged 40-60 years, free from serious complications were selected from the OPD (out patient department) of the Hospital of Punjab Agricultural University, Ludhiana and equally divided into three groups, viz. $E_1$, $E_2$ and C. Collection of data pertaining to general and diabetic information was done through a questionnaire.

***Dietary Survey:*** Dietary intake of the subjects was recorded for three consecutive days by "24 hours recall-cum-weighment method", using standardized containers, of all the three groups before and after the study. The average daily nutrient intake of the diet was calculated by using MSU nutriguide computer programme (Song et al. 1992). The average raw amounts in gram of each and every item of food consumed

for three consecutive days for each subject was fed in the hardware and nutritive value of diets were recorded.

***Haematological Profile of the Subjects:*** Haemoglobin (Hb), Packed cell volume (PCV), Red blood cell (RBC) count was analysed by standardized methods for all the subjects of three groups before and after the study. Further, to assess iron status of the subjects mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and mean corpuscular haemoglobin concentration (MCHC) were calculated.

***Supplementation of Spirulina:*** Spirulina in the form of "SUNOVA spirulina" capsules were procured from market. As per composition each capsule contained 500 mg of spirulina, so 2 capsules were used to supplement 1 g of spirulina to $E_1$ and 4 capsules were used to supplement 2 g of spirulina to $E_2$, whereas subjects of group C were not given any supplementation. The supplementation was done for a period of 2 months. The subjects were advised to consume capsules before breakfast and lunch and were monitored regularly. All the subjects were also on oral hypoglycemic drugs as prescribed by the physician during the study period.

***Statistical Analysis:*** The data was analyzed with the help of various simple statistical tools such as mean, standard error (SE), percentages etc. Student't' test was applied to test and their statistical significance was ascertained using a Microsoft Excel Computer Programme package on all the parameters.

## RESULTS AND DISCUSSION

***Diabetic Information of the Subjects***: As per demographic information of the present study, the mean age of onset and duration of diabetes was 46.3±1.69, 45.95±1.58 and 47.6±1.49 yrs and 8.37±1.48, 7.89±1.33 and 6.32±1.06 yrs in $E_1$, $E_2$ and C groups, respectively. Majority of the subjects i.e. 55, 65 and 50 per cent had vision problems and 30, 40 and 40 per cent subjects had hypertension in the three groups, respectively. The most common symptoms observed in the three groups were tiredness, frequent urination, excessive thirst and frequent hunger. It was observed that the family history of the disease due to diabetic mother was more prevalent among the subjects as compared to diabetic father or both diabetic parents (Table 1).

**Table 1: Diabetic information of the subjects (n = 20 each)**

| *Particular* | *$E_1$* | *$E_2$* | *C* |
|---|---|---|---|
| Age of onset (yrs) (Mean±SE) | 46.3±1.7 | 45.95±1.6 | 47.6±1.5 |
| Duration of diabetes (yrs) (Mean±SE) | 8.37±1.5 | 7.89±1.3 | 6.32±1.1 |
| *Mode of Onset* | | | |
| Typical symptoms | 14 (70) | 19 (95) | 14 (70) |
| Under physical stress | 6 (30) | 1 (5) | 6 (30) |
| *Medical Problems Diagnosed** | | | |
| Hypertension | 6 (30) | 8 (40) | 8 (40) |
| Foot problems | - | - | 2 (10) |
| Kidney | 1 (5) | - | - |
| Vision | 11 (55) | 13 (65) | 10 (50) |
| CAD | 1 (5) | - | 1 (5) |
| Skin problems | 1 (5) | - | - |

Figures in parenthesis are percentages
* Multiple responses

### Clinical Manifestation

In the present study the more prevalent signs observed in most of the subjects were fatigue, anorexia, lethargy and paleness of eyes. It was indicated that 20, 75 and 90 per cent of the subjects suffered from fatigue in $E_1$, $E_2$ and C group, respectively whereas, corresponding percentages after the study decreased to 10, 55 and 75 per cent, respectively. The figures for anorexia were as 45, 85 and 85 per cent and 25, 60 and 75 per cent before and after the study among the subjects of all the three groups, respectively. Further, 50, 55 and 70 per cent subjects suffered from lethargy in $E_1$, $E_2$ and C group, respectively, which decreased to 40, 30 and 65 per cent at end of the study. It was also observed that only one subject had shown the sign of paleness of eyes in $E_2$ group. Further, this symptom disappeared at the end of the study because of spirulina supplementation. The results of the above data indicated that clinical signs were more marked in C group followed by $E_2$ group. There was appreciable reduction in the clinical signs of $E_1$ and $E_2$ group after spirulina supplementation for two months. The presence of symptoms was due to occurrence of diabetes among the subjects in all the three group (Table 2).

***Nutrient Intake of the Subjects:*** The average daily nutrient intake before and after the study period is given in Table 3.

***Energy and Protein:*** The initial mean energy

**Table 2: Clinical Assessment of the subjects* (n = 20 each)**

| *Signs* | $E_1$ | | $E_2$ | | *C* | |
|---|---|---|---|---|---|---|
| | *Initial* | *Final* | *Initial* | *Final* | *Initial* | *Final* |
| Pale Eyes | - | - | 1( 5) | - | - | - |
| Fatigue | 4(20) | 2(10) | 15(75) | 11 (5) | 18(90) | 15(75) |
| Anorexia | 9(45) | 5(25) | 17(85) | 12(60) | 17(85) | 15(75) |
| Lethargy | 10(50) | 8(40) | 11(55) | 6(30) | 14(70) | 13(65) |

Figures in parenthesis are percentages
*Multiple Responses

**Table 3: Mean daily nutrient intake of the subjects (Mean±SE) (n = 20 each)**

| *Food group* | *Initial* | *Final* | *Difference* | *t-value* | *Suggested intakes ++* |
|---|---|---|---|---|---|
| *Energy (k cal)* | | | | | |
| $E_1$ | 2001 | 1867 | -134 | 2.91** | 1500 |
| $E_2$ | 2231 | 1922 | -309 | 8.11** | |
| C | 2062 | 2024 | -38 | 0.54 NS | |
| *Carbohydrates (g)* | | | | | |
| $E_1$ | 268±11.0 | 262± 9.0 | -6 | 0.77 NS | 235 |
| $E_2$ | 296±11.6 | 267±10.4 | -29 | 2.83** | |
| C | 283± 8.5 | 284± 6.5 | 1 | - | |
| *Protein (g)* | | | | | |
| $E_1$ | 68±15.3 | 65± 9.0 | -3 | 1.34 NS | 65 |
| $E_2$ | 77± 3.4 | 67± 2.6 | -10 | 3.82** | |
| C | 73± 3.0 | 72± 1.8 | -1 | 0.12 NS | |
| *Total fat (g)* | | | | | |
| $E_1$ | 73± 6.0 | 62± 3.0 | -11 | 2.26* | 34 |
| $E_2$ | 82± 4.8 | 65± 2.5 | -17 | 4.08** | |
| C | 71± 4.7 | 66± 3.7 | -5 | 0.96 NS | |

Figures with different superscripts in a column differ significantly
++ Raghuram et al.. (1993)
NS non significant
NA data not available
** Significant at 1 %
• Significant at 5 %

intake of subjects decreased from 2001, 2231 and 2062 Kcal to 1867, 1922 and 2024 Kcal after study in $E_1$, $E_2$ and C group, respectively. It was observed that the mean energy intake decreased significantly ($p \leq 0.01$) in $E_1$ and $E_2$ groups due to decreased intake of cereals, fat and sugar. Whereas, non-significant decrease in the energy intake was observed in C group after the study. The maximum decrease was observed in $E_2$ group. Kapoor (2001) reported a significant decrease in energy intake in diabetic subjects after intervention. The average daily intake of protein before and after the study was 68, 77 and 73 g and 65, 67 and 72 g in $E_1$, $E_2$ and C group, respectively. There was a non-significant decrease in the protein intake of the subjects of group $E_1$ and C and a significant decrease was observed ($p \leq 0.01$) in the protein intake of the subjects of group $E_2$ after two months of the study. It was observed that initially protein intake in all the three groups was higher than the suggested intake of 65 g and after two months protein intake was marginally adequate in $E_1$ and $E_2$ groups but higher in C group.

***Carbohydrates:*** The mean daily intake of carbohydrates was 268, 296 and 283 and 262, 267 and 284 g/day before and after the study in $E_1$, $E_2$ and C group, respectively. There was a non-significant decrease in the intake of carbohydrates by the subjects of group $E_1$ and C and a significant decrease ($p \leq 0.01$) in the carbohydrates intake in the subjects of group $E_2$ was observed after two months of the study. Further, it was observed that the carbohydrates intake in the three groups was higher than the suggested value of 235 g/day given by Raghuram et al. (1993). Mann (1997) reported that in NIDDM subjects the high carbohydrates diet worsened glycemic control and had been associated with increased TG, decreased HDL-C which were existing risk of CHD.

***Fats and Oils:*** The daily intake of total fats and oils among the subjects of all the three groups was 73, 82 and 71 g/day before the study. The corresponding values after the study were 62, 65 and 66 g/day in $E_1$, $E_2$ and C group, respectively. There was a significant decrease in the intake of fats and oils by the subjects of group $E_1$ ($p \leq 0.05$) and $E_2$ ($p \leq 0.01$) were observed. However, incase of C group a non-significant decrease was observed after two months of the study. Wang et al. (2003) reported that the incidence of diabetes was significantly and positively associated with proportion of total saturated fat in diet. The decreased fat intake in all the three groups could be attributed to knowledge gain via media, pamphlets and internet.

***Per cent Contribution of Carbohydrates, Protein and Fat to the Total Energy Intake:*** The initial dietary carbohydrates intake contributed to 53.6, 53.1 and 54.9 per cent of total calories in $E_1$, $E_2$ and C group, respectively, while, the percentage increased to 56.1, 55.7 and 56.2 per cent in the three groups at the end of the study. Initially, the average contribution of dietary protein to total energy was 13.6, 13.8 and 14.2 per cent in $E_1$, $E_2$ and C group, respectively which increased significantly. Though, the total protein intake reduced after the study, but the percent contribution of protein to total energy significantly increased to 13.9 and 13.8 in $E_1$ and $E_2$ groups, respectively after the supplementation of spirulina. While, incase of C group corresponding values remained constant at end of study. The initial dietary total fat intake contributed to 32.8, 33.1 and 30.9 per cent of total calories in $E_1$, $E_2$ and C group, respectively, while, the percentage decreased to 29.9, 30.4 and 29.6 per cent in the three groups at the end of the study. The reduction in per cent contribution of carbohydrates, fat and protein to total energy intake in all the three groups could be due to seasonal changes, information via media, internet, nutrition pamphlets and other such sources.

***Vitamins:*** The data in Table 4 shows average dietary intake of vitamins i.e. thiamine, riboflavin, niacin, ascorbic acid and folic acid.

***Thiamine and Riboflavin:*** It was observed that the mean daily intake of thiamine before and after the study was 1.7, 1.9 and 1.8 mg and 1.6, 1.7 and 1.8 mg in $E_1$, $E_2$ and C groups, respectively which were higher when compared to ICMR (2003) recommendations. The average daily intake of thiamine decreased non-significantly in the subjects of $E_1$ and $E_2$ groups, whereas the corresponding figures remained constant incase of group C during the study period. Kapoor (2001) and Aggarwal (2003) also reported a higher thiamine intake by the subject of non-insulin dependent diabetic when compared to ICMR recommendations. The mean intake of riboflavin be-

**Table 4: Mean daily intakes of vitamins by the subjects (Mean±SE) (n = 20 each)**

| *Vitamins* | *Initial* | *Final* | *Difference* | *t-value* | *Suggested intakes #* |
|---|---|---|---|---|---|
| *Thiamine (mg/dl)* | | | | | |
| $E_1$ | 1.7± 0.06 | 1.6± 0.06 | -0.1 | 1.06 NS | 1.2 |
| $E_2$ | 1.9± 0.09 | 1.7± 0.07 | -0.2 | 1.81 NS | |
| C | 1.8± 0.05 | 1.8± 0.04 | 0 | - | |
| *Riboflavin (mg/dl)* | | | | | |
| $E_1$ | 1.5± 0.09 | 1.7± 0.12 | 0.2 | - | 1.4 |
| $E_2$ | 1.6± 0.11 | 1.7± 0.10 | 0.1 | - | |
| C | 1.5± 0.10 | 1.6± 0.09 | 0.1 | - | |
| *Niacin (mg/dl)* | | | | | |
| $E_1$ | 13± 0.60 | 13± 0.64 | 0 | 0.28 NS | 16 |
| $E_2$ | 15± 1.21 | 16± 0.99 | 1 | - | |
| C | 14± 0.53 | 14± 0.43 | 0 | - | |
| *VitaminC (mg/dl)* | | | | | |
| $E_1$ | 134±25.5 | 135±23.3 | 1 | - | 40 |
| $E_2$ | 105±12.9 | 131±13.8 | 26 | - | |
| C | 123±23.5 | 146±25.8 | 23 | - | |
| *Folic Acid (µg/dl)* | | | | | |
| $E_1$ | 194±11.2 | 192±11.8 | -2 | 0.14 NS | 100 |
| $E_2$ | 223±15.9 | 214±12.6 | -9 | 0.48 NS | |
| C | 196±12.1 | 211±13.4 | 15 | - | |

Figures with different superscripts in a column differ significantly
# ICMR (2003)
NS non-significant

fore the study was 1.5, 1.6 and 1.5 mg in $E_1$, $E_2$ and C group, respectively. The corresponding values after two months of study were 1.7, 1.7 and 1.6 mg. A non-significant increase in dietary intake of riboflavin was observed in all the three groups after the study.

***Niacin and Folic Acid:*** The mean daily intake of niacin was 13, 15 and 14 mg/day among the subjects of all the three groups. There was not much change in the intake in all the three groups. However, after two months the intake of niacin among the subjects was 13, 16 and 14 mg/day in $E_1$, $E_2$ and C group, respectively and was lower than the ICMR (2003) recommendations. Similarly, lower intake of niacin was also observed by Kapoor (2001) and McCarty et al. (2002). The average daily folic acid intake was 194, 223 and 196 mg/day in $E_1$, $E_2$ and C group, respectively before the study. The corresponding values after the study were 192, 214 and 211 mg/day. A non-significant decrease was observed in the folic acid intake among the subjects of $E_1$ and $E_2$ groups after the supplementation of spirulina, whereas a non-significant increase was observed in C group after the study. Though, there was a decrease in the folic acid intake, still the intake in all the three groups was higher than the suggested intake of 100 mg/day by ICMR (2003) before and after the study. It could be due to increased consumption of fruits i.e. guava, *ber*, pineapple and citrus fruits etc. The present results of the study were in line with Aggarwal (2003).

***Ascorbic Acid:*** The mean intake of ascorbic acid in diets at the beginning and at the end of the study was 134, 105 and 123 mg/day and 135, 131 and 146 mg/day in $E_1$, $E_2$ and C group, respectively. A non-significant increase was observed in daily intake of diet rich in ascorbic acid among the subjects of all the three groups after two months of study period which was much higher than the recommended value of 40mg/day by ICMR (2003). This increase in ascorbic acid intake could be due to seasonal changes due to more availability of citrus fruits, *amla* and green leafy vegetables as the survey was conducted in winter season. Rondanelli et al. (2000) reported that average daily intake of Vitamin C met the suggested values.

## Minerals

The data in Table 5 shows average dietary intake of calcium, phosphorus, magnesium, zinc and iron.

***Calcium and Phosphorus:*** The mean daily initial intake of calcium was 1264±74.81,

**Table 5: Mean daily intake of minerals by the subjects (Mean±SE) (n = 20 each)**

| *Minerals* | *Initial* | *Final* | *Difference* | *t-value* | *Suggested intakes ++* |
|---|---|---|---|---|---|
| *Calcium (mg/dl)* | | | | | |
| $E_1$ | 1264±74.81 | 1192±59.20 | -72 | 0.81 NS | 400 |
| $E_2$ | 1440±89.44 | 1240±56.96 | -200 | 2.18** | |
| C | 1299±70.09 | 1268±71.05 | -31 | 0.36 NS | |
| *Phosphorus (mg/dl)* | | | | | |
| $E_1$ | 1776±63.84 | 1768±55.23 | -8 | 0.15 NS | 400 |
| $E_2$ | 2003±87.97 | 1727±60.72 | -276 | 3.63*** | |
| C | 1858±62.36 | 1853±50.26 | -5 | 0.08 NS | |
| *Magnesium (mg/dl)* | | | | | |
| $E_1$ | 366±20.44 | 375±23.56 | 9 | - | 350 |
| $E_2$ | 373±22.56 | 375±20.26 | 2 | - | |
| C | 378±15.01 | 410±16.41 | 32 | - | |
| *Zinc (mg/dl)* | | | | | |
| $E_1$ | 7± 0.35 | 8± 0.30 | 1 | - | 15.5 |
| $E_2$ | 7± 0.33 | 8± 0.26 | 1 | - | |
| C | 7± 0.22 | 7± 0.21 | 0 | - | |
| *Iron (mg/dl)* | | | | | |
| $E_1$ | 22± 2.51 | 24± 2.16 | 2 | - | 28 |
| $E_2$ | 21± 1.95 | 27± 3.19 | 6 | - | |
| C | 21± 2.15 | 25± 2.99 | 4 | - | |

Figures with different superscripts in a column differ significantly
++ ICMR (2003)
** Significant at 1 %
* Significant at 5 %
NS non significant

1440±89.44 and 1299±70.09 mg in $E_1$, $E_2$ and C group, respectively which decreased to 1192±59.20, 1240±56.96 and 1268±71.05 after the study and was higher than ICMR (2003) recommendations. A statistically significant ($p \leq 0.05$) decrease was observed in the intake of calcium among the subjects of $E_2$ group, whereas intake of calcium in $E_1$ and C group decreased non-significantly at the end of study. Similar results were also reported by Vasanthamani and Savita (2001). The average daily initial intake of phosphorus was 1776, 2003 and 1858 mg/day in $E_1$, $E_2$ and C group, respectively. The corresponding intake after two months was 1768, 1727 and 1853 mg/day. A statistically significant ($p \leq 0.01$) decrease was observed in the intake of phosphorus among the subjects of $E_2$ group whereas, intake of phosphorus in $E_1$ and C group decreased non-significantly at the end of study. The intake of calcium and phosphorus was higher among the subjects due to more intake of milk and milk products. Gross et al. (2002) also reported higher intake of phosphorus by the diabetic subjects.

***Magnesium and Zinc:*** The average daily initial magnesium intake of 366, 373 and 378 mg/day increased to 375, 375 and 410 mg/day after the two months of study period. A non-significant increase was observed among the subjects of all the three groups. The present data further, depicted that the magnesium intake in all the three groups before and after the study was more than that recommended dietary allowances of 350 mg/day. The average daily intake of zinc was 7µg/day each and 8 µg/day for $E_1$ and $E_2$ each and 7 µg/day for C group, respectively before and after the study. It was observed that there was a non-significant increase in intake by the subjects in $E_1$ and $E_2$ groups whereas, the intake remained constant in group C after the study. The present data depicted that the zinc intake in all the three groups before and after the study was less when compared to RDA of 15.5 µg/day. Similarly, Aggarwal (2003) reported lower intake of zinc by the diabetic subjects.

***Iron:*** The average daily intake of iron was 22, 21 and 21 mg/day and 24, 27 and 25 mg/day in $E_1$, $E_2$ and C group, respectively before and after the study. The intake of iron increased non-significantly in all the three groups after the study. Though, there was an increase in the iron intake, still the intake in all the three groups was less than the recommended intake of 28 mg/day before and after the study. The increase in intake of iron could be due to seasonal availability of green leafy vegetables during winter. Vasanthamani and Savita (2001) reported an inadequate iron intake by diabetic subjects.

## Hematological Profile of the Subjects

***Haemoglobin Level (Hb)*:** The mean levels of Hb of the subjects are given in Table 6. The

**Table 6: Haematological profile of subjects before and after the study (n = 20 each)**

| *Variable* | *Group* | *Initial* | *Final* | *Difference* | *t-value* | *Reference standard* |
|---|---|---|---|---|---|---|
| Hb (g/dl) | $E_1$ | 12.6±0.2 | 13.3±0.2 | 0.7 | - | 12-16+ |
| | $E_2$ | 12.5±0.2 | 14±0.2 | 1.5 | - | |
| | C | 12.4±0.2 | 12.5±0.2 | 0.1 | - | |
| PCV (%) | $E_1$ | 37±1.0 | 40±1.2 | 3 | - | 36-47++ |
| | $E_2$ | 36±0.8 | 40±0.9 | 4 | - | |
| | C | 36±0.5 | 37±0.6 | 1 | - | |
| RBC count ($10^6$/mm$^3$) | $E_1$ | 4.3±0.07 | 4.5±0.09 | 0.2 | - | 3.9-5.6++ |
| | $E_2$ | 4.2±0.05 | 4.4±0.07 | 0.2 | - | |
| | C | 4.2±0.04 | 4.2±0.03 | 0 | $0.59^{NS}$ | |
| MCV ( fl ) | $E_1$ | 87±1.20 | 90±1.10 | 3 | - | 84-95+ |
| | $E_2$ | 86±1.08 | 89±1.11 | 3 | - | |
| | C | 85±0.88 | 88±1.07 | 3 | - | |
| MCHC (%) | $E_1$ | 34±0.45 | 33±0.45 | -1 | 3.16** | 33-38+ |
| | $E_2$ | 35±0.42 | 35±0.55 | 0 | 2.28* | |
| | C | 35±0.43 | 34±0.51 | -1 | $0.82^{NS}$ | |
| MCH (pg) | $E_1$ | 29.7±0.34 | 29.9±0.31 | 0.2 | - | 28-32+ |
| | $E_2$ | 30±0.35 | 31±0.27 | 1 | - | |
| | C | 29±0.42 | 30±0.34 | 1 | - | |

Figures with different superscripts in a column differ significantly

** Significant at 1 % + Harper (1965)

* Significant at 5 % ++ Davidson and Passmore (1987)

mean initial levels of Hb of the subjects were 12.6±0.9, 12.5±0.8 and 12.4±0.9 g/dl in $E_1$, $E_2$ and C group, respectively. While, the corresponding values after the supplementation were 13.3±0.2, 14±0.2 and 12.5±0.2 g/dl. There was increase in the Hb levels of $E_1$ and $E_2$ group because spirulina contained highly available form of iron, appreciable amount of calcium, magnesium, copper, chromium and selenium and vitamins namely vitamin $B_{12}$, folic acid and vitamin $B_6$ which are essential for haemopoiesis (Devi and Uma 2005). Taekuchi (1978) reported 21 % increase in haemoglobin after spirulina supplementation (4g/day) for 30 days. Another study by Kaur (2002) also recorded a significant increase in haemoglobin levels among girls after consuming 1 g spirulina/day for a period of two months.

***Packed Cell Volume (PCV)*:** The mean values of the PCV among all subjects were 37±4.6, 36±3.6 and 36±2.1 per cent in $E_1$, $E_2$ and C group, respectively. However, after the end of the study the values increased to 40±1.2, 40±0.9 and 37±0.6 per cent in $E_1$, $E_2$ and C group, respectively. There was a non-significant increase in PCV values in all the groups and at end of the study there was however slight increase in the subjects of C group. The increase in PCV values at the end of study could be due to intake of spirulina supplementation.

***Red Blood Cell Count (RBC count)*:** The mean values of the RBC among all the subjects were 4.3±0.07, 4.2±0.05 and 4.2±0.04 $10^6/mm^3$ and 4.5±0.09, 4.4±0.07 and 4.2±0.03 $10^6/mm^3$ in $E_1$, $E_2$ and C group, respectively. The study revealed that there was no change in the C group as the values remained constant. There was a non-significant increase in the RBC values of all the subjects at the end of the study. However, the values in all the three groups were within the normal range of 3.9–5.6 x $10^6/mm^3$.

***Mean Corpuscular Volume (MCV):*** The initial mean values of MCV among the subjects of $E_1$, $E_2$ and C groups were 87±1.20, 86±1.08 and 85±0.88 fl which increased to 90±1.10, 89±1.11 and 88±1.07 fl among the subjects of $E_1$, $E_2$ and C group, respectively at the end of the study, but it was non-significant. The mean values before and after the study were within the normal range of 84 – 95 fl.

***Mean Corpuscular Haemoglobin Concentration (MCHC):*** The mean values of MCHC among the subjects were 34±0.45, 35±0.42 and 35±0.43 per cent and 33±0.45, 35±0.55 and 34±0.51 per cent in $E_1$, $E_2$ and C group before and after the study, respectively. There was a significant ($p \leq 0.01$) decrease in $E_1$ group (33±0.45) and group $E_2$ also showed a significant ($p \leq 0.05$) decrease. On the other hand, incase of C group there was a non-significant decrease. However, the mean MCHC values were within the normal range of 33 – 38 g/dl.

***Mean Corpuscular Haemoglobin (MCH):*** The mean values of MCH among subjects belonging to $E_1$, $E_2$ and C group were 29.7±0.34, 30±0.35 and 29±0.42 pg, respectively. These increased to 29.9±0.31, 31±0.27 and 30±0.34 pg, respectively at end of the study. There was non-significant increase in all the groups at the end of the study. The values of MCH among all the three groups were within the normal range of 28 – 32 pg before and at end of the study.

***Coefficient of Correlation (r) between Nutrient Intakes with Hematological Profile:*** Table 7 depicts the relationship between nutrient intake and hematological parameters. It was observed that energy intake was positively and significantly ($p \leq 0.05$) correlated to haemoglobin (Hb) (r=0.484) and it was highly significant ($p \leq 0.01$) correlated with PCV (r=0.627) and RBC (r=0.636). Further, Haemoglobin and PCV were positively and significantly ($p \leq 0.05$) correlated to protein intake (r=0.443) and (r=0.557), respectively. Whereas, protein intake was significantly ($p \leq 0.01$) correlated to RBC (r=0.565). There was a positive and significant ($p \leq 0.05$) correlation between iron and haemoglobin (r=0.496). Further, it was highly significant ($p \leq 0.01$) to PCV (r=0.627) and RBC (r=0.585). Ascorbic acid was significantly ($p \leq 0.05$) correlated to haemoglobin (r=0.509).

## CONCLUSION

It is suggested that 2 g of spirulina supplementation can improve haematological status of the NIDDM subjects as it has highly available form of iron present in spirulina. It has a pigment called phycocyanin which helps to strengthen the body's defence system and it also helps in the retardation of secondary complications, hence it improve general health and vigour of NIDDM subjects.

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