10th Conf. Agric. Dev. Res., Fac. Agric., Ain Shams Univ., Cairo, Egypt, 2006
Annals Agric. Sci., Sp. Issue, 1, 87-97, 2006

BIOLOGICAL EVALUATION OF LENTIL-BASED SOUP BLENDS AS DIABETIC FOOD

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ABSTRACT

Some of legumes and cereals are recommended for better glucose control in persons with diabetes. The goal of this study was to prepare lentil-based soup blends with low glycemic index as diabetic diets for Type 2 diabetes. To achieve this goal 18 % of lentil soup blend was replaced with defatted chickpea, mung beans or wheat germ meals as additional sources of dietary fiber and protein. Blood glucose responses of these blends by10 persons with Type 2 diabetes were assayed and glycemic index was calculated. Fortification of lentil soup blend with the investigated meals led to increase its protein and dietary fiber contents resulted in reduction of glycemic index (ranged from 47.6 to 40.7 %). The low glycemic indexes obtained in this study may also refer to low calorie (271.95 to 304.27 kcal) of the investigated soups. According to the obtained glycemic indexes supplementation of lentil soup blend with wheat germ led to lesser response in plasma glucose followed by fortification with mung beans. Addition of chickpea led to little increase in glycemic index compared other treatments, although all glycemic indexes were in range of low glycemic foods.

Keywords: Legumes, Lentil, Wheat germ, Diabetes, Glycemic index

INTRODUCTION

Diabetes is a growing problem in the current modern society. It is difficult to estimate the total number of population suffering from this problem, as a large number of people are not aware that they are diabetic (**Mokdad *et al* 2000 & 2001**). Diabetes is classified into two types according to American Diabetes Association (**ADA, 1997a**). Type 1 is due to an almost complete destruction of pancreatic B cells which represents a consequence of an autoimmune process. Type 2 is usually develops in elderly individuals who are very often over weight. The later has a very slow onset (it may be asymptomatic for several years) and does not necessarily require insulin treatment. The most alarming new development in this trend is the rise in the incidence of Type 2 diabetes. The rising prevalence of

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(Received July 8, 2006)
(Accepted August 23, 2006)

Type 2 diabetes is commonly attributed to changes in dietary patterns (**Sherwin *et al* 2003**) and lifestyle characteristics such as obesity (**Astrup and Finer, 2000**) physical activity (**Paffenbarger *et al* 1997 and Turner *et al* 1999**) and smoking (**Mikhailidis *et al* 1998**).

The glycemic index (GI) is an *in vivo* measurement based on the glycemic response to carbohydrate containing foods and allows foods to be ranked on the basis of digestion and absorption rates of the carbohydrates that they contain (**Jenkins *et al* 1981**). They defined the Glycemic index as the incremental area under the blood glucose response curve of a 50 g carbohydrate portion of a test food expresses as a percent of the response to the same amount of carbohydrate from a standard food taken by the same subject.

Diet is said to be the 'cornerstone' of management of diabetes. Yet the recommended dietary guidelines remain controversial and relatively few patients succeed is being well controlled on diet alone (**Sahyoun *et al* 2005**). The goals of dietary therapy for management of diabetes mellitus, as outlined by The American Diabetes Association (**ADA, 1997a; 1997b**), include normalization of blood glucose levels, optimization of food lipoprotein levels provision of adequate energy for attaining a desirable body weight, and prevention of acute and chronic complications.

Today, there is a strong effort being made to increase the legume intake in populations with high prevalence of diabetes, obesity and cardiovascular diseases (**Duranti, 2006**). Because of the low glycemic index (GI) and the high content of indigestible fibres, dry legumes are claimed to help glycemic control in diabetic individuals (**Duranti, 2006**). Moreover, dry legumes may contribute to prevent insulin-resistance, which represents the problem to Type 2 diabetes.

Therefore, the aim of this study is to prepare a low glycemic index legume-based diet by fortification of lentil soup by fat free chickpea, mung bean or wheat germ as additional sources of dietary fiber and proteins. Moreover, this work is designed to provide information on glycemic index of lentil-based blends in Type 2 diabetes.

MATERIAL AND METHODS

Raw materials

The raw materials used in this study include lentil (*Lens culinaris* Medik), chickpeas (*Cicer arietinum* L.), tomato, carrots, onion, and garlic and were purchased from the local market. Mung bean (*Phaseolus aureus* V2010) was obtained from Agricultural Research Center, Legume Department, Ministry of Agriculture, Giza, Egypt. Wheat germ was purchased from North Cairo Flour Mills Company, Shoubra El-Kheima, Egypt.

Preparation of protein concentrate

Legume seeds (chickpeas and mung bean) washed, dried and ground to obtain the seed meals. These meals and wheat germ were defatted with petroleum ether (**A.O.A.C., 2000**). Protein concentrates were prepared from defatted meals (chickpeas, mung bean and wheat germ) using ethanol 70% (**Baker *et al* 1979**).

Preparation of lentil-based blends

Lentil blends consists of ground lentil (as a main component), dried vegetables, and some other additives (Table 1). The vegetables (tomato, carrot, onion and garlic) were separately dried under vacuum at 60°C for 12-20 h. 18% of lentil were replaced with chickpeas, mung bean or wheat germ as sources of protein and dietary fiber.

The prepared dried blends were packed in polypropylene bags and stored at 4°C for subsequently use.

Table 1. Component percentage (w/w) of lentil-based soup blends.

Components %	Blends #			
	L	LC	LM	LW
Lentil	68.1	50.1	50.1	50.1
Chickpeas	-	18	-	-
Mung bean	-	-	18	-
Wheat germ	-	-	-	18
Tomato	8	8	8	8
Carrot	4.5	4.5	4.5	4.5
Onion	6.5	6.5	6.5	6.5
Salt	10	10	10	10
Others*	2.9	2.9	2.9	2.9

The main components in lentil and lentil-based blends are Lentil (L); lentil–Chickpea (LC); Lentil–Mung bean (LM); and Lentil – Wheat germ (LW).
* Cumin (0.5%), Coriander (0.5%), Sodium bicarbonate (0.2%), Garlic (0.5%), Turmeric (02%), Glutamic acid (0.5%), Black pepper (0.5%)

Chemical composition of lentil-based blends

Moisture, fat, ash, protein (N×6.25 for legume; N×5.7 for wheat germ) and total dietary fiber (TDF) were determined according to **A.O.A.C. (2000)**. Shiffer-Somogi micro method (**A.O.A.C., 2000**) was applied to determine the total carbohydrates.

Caloric values of different lentil-based blends were calculated according to the method described by **Dougherty *et al* (1988)**. Briefly, energy (E) as calories per 100 g of blend was calculated using the following equation:

E = 4 (protein % + digestible carbohydrates %) + (9 × Fat %).

Preparation of lentil-based soups

Lentil soup and lentil-based soups were prepared by resuspended 60 gm of dried blends (prepared as mentioned above) and cooked in 1 L boiled water for 15 min.

Sensory evaluation

Sensory evaluation of the cooked soups was performed based on the method of evaluation of the supplementary foods (**Nutter *et al* 1959**). The sensory parameters were appearance, colour, taste, odour, homogeneity, absence of precipitation, absence of particles, after taste).

Biological evaluation of lentil-based soups

The prepared lentil and lentil-based soups were biologically evaluated by ten Type 2 diabetic subjects (three male and seven female). Their ages ranged from 38 to 60 years and their body mass index (BMI) ranged from 25.8 to 33.6 Kg/m^2. The subjects were in a physiological fasted state (10 -12 h) before the beginning of the experiment. Fifty grams of available carbohydrate from lentil soup (L) or lentil-based soups (lentil soup supplemented with chickpea (LC), mung bean (LM) or wheat germ (LW)) were consumed by each subject. This diet was consumed along 10 min. Tap water was allowed during consumption of the diet and during the period of sampling (2 h). Venous blood samples were taken for the fasting subjects (0 min) then 30, 60, 90 and 120 min after consumption of the soup. For each subject, the test was applied in three separated days (Triplicates). Instead of soups 50 g glucose was applied as a standard treatment (S). Blood sample (0.5 ml) was collected with disposable syringe in plastic tubes containing sodium fluoride (as anticoagulant). The samples were centrifuged to separate blood plasma. Blood glucose was determined in plasma samples by a glucose oxidase (EC 1.1.3.4) method (Human Pharma Latain kit) according to supplier.

Glycemic Index

The blood glucose response is expressed as the glycemic index of the food to allow comparison on the basis of equal available carbohydrate content. The area under the blood glucose response curve for glucose is expressed as 100, and the responses to equal available carbohydrate portions of studied soup blends are expressed as a percentage of the glucose value of the same subject. The incremental area under the blood glucose-response curve was measured geometrically excluding beneath the fasting level (**Jenkins *et al* 1981; Wolever *et al* 1991 and Wolever *et al* 1994**).

Statistical analysis

Data were analyzed with SAS software (SAS Institute, Cary, N.C.) using SAS analysis of variance (PROC ANOVA) and Tukey models procedure.

RESULTS AND DISCUSSION

The Type 2 diabetic patients (mean of age (±SE) 49.5 ± 2.25) of the present study were selected randomly from the same social class, three males and seven females (**Table 2**). The mean of body mass index (BMI) of the investigated subjects was 29.4±2.7 (mean ± SE), range(25.8 and 33.6) kg/m^2. This range of BMI indicated that the present study was applied in mild to moderate obese patients(**Lovejoyand DiGirolamo, 1992**).

Table 2. Clinical information of 10 diabetic subjects

Subject	Gender	Age (year)	Weight (kg)	Length (m)	BMI (kg/m^2)
1	Male	41	73	1.6	28.5
2	Male	56	87	1.7	30.1
3	Male	45	66	1.6	25.8
4	Female	50	87	1.7	30.1
5	Female	55	65	1.39	33.6
6	Female	45	78	1.7	26.9
7	Female	50	73	1.52	31.6
8	Female	38	94	1.7	32.5
9	Female	55	82	1.7	28.3
10	Female	60	60	1.5	26.6
Mean (SE)		49.5(2.25)	76.5(3.49)	1.61(0.03)	29.4(0.83)

BMI= Body Mass Index SE= Standard Erro

They classified obesity based on BMI into three classes; mild obesity (BMI between 25 and 30 kg/m^2), moderate obesity (BMI between 30 and 35 kg/m^2) and severe obesity (BMI > 35 kg/m^2).

The prepared soups were sensory evaluated by the investigated subjects. Significant differences ($p<0.05$) were noticed between lentil soups and lentil-based soups in the homogeneity, the appearance and the colour (Table 3). However, no significant differences ($p > 0.05$) were obtained in the after-test parameter. Generally, all supplemented lentil soups used in this study had high scores in the overall acceptability, although, significant differences were recorded in most of the tested parameters (Table 3).

Results of the chemical analysis in the prepared lentil and lentil-based blends are presented in Table 4. Supplementation of lentil soup with wheat germ (LW) led to significant ($p<0.05$) increase in protein, dietary fiber and ash contents. However, the lowest carbohydrate (54.9%) and lowest energy (271.95) contents were determined in the same soup blend (LW).

Replacement of a portion (18%) of lentil by chickpea and mung beans led also to increase protein and dietary fiber contents of supplemented soup blends (Table 4). On the other hand, no significant difference ($p>0.05$) was obtained in the fat content when lentil blend was supplemented with chickpea, mung beans or wheat germ.

The mean of incremental blood glucose responses up to 120 min following intake of the four prepared blend soups in addition to the standard treatment

Table 3. Sensory evaluation of the prepared lentil and lentil-based soups

Blends #	Sensory Parameters *								
	Appearance	Colour	Taste	Odour	Homogeneity	Absence of Precipitation	After Taste	Absence of Particles	Total Score
L	9.57^{a}	9.71^{a}	9.14^{a}	9.42^{a}	9.57^{a}	19.14^{a}	9.14^{a}	19.14^{a}	94.85^{a}
LC	7.8^{b}	7.85^{b}	8.28^{ab}	8.71^{ab}	8.14^{b}	18.00^{ab}	9.00^{a}	17.71^{ab}	85.57^{b}
LM	6.85^{b}	6.85^{b}	7.28^{b}	7.57^{b}	7.71^{b}	16.57^{b}	8.42^{a}	16.57^{b}	76.42^{b}
LW	7.85^{b}	7.71^{b}	7.57^{b}	8.71^{ab}	8.14^{b}	17.00^{b}	9.14^{a}	16.85^{ab}	81.71^{b}

* Means with the same letter or letters within the same colum are not significantly different ($p<0.05$)
\# Blends (L, LC, LM and LW) are described in **Table (1)**

Table 4. Chemical constituents of different lentil-based blends

Chemical constituents* %	Blends #			
	L	LC	LM	LW
Moisture	10.02^{a}	8.98^{d}	9.25^{b}	9.12^{c}
Protein	21.10^{d}	24.00^{c}	27.07^{b}	29.32^{a}
Fat	1.63^{c}	1.64^{b}	1.64^{a}	1.63^{d}
Total carbohydrate	63.81^{a}	59.87^{b}	57.28^{c}	54.90^{d}
Total dietary fiber	12.51^{d}	15.27^{b}	13.18^{c}	19.90^{a}
Ash	13.50^{d}	14.06^{b}	13.99^{c}	14.25^{a}
Calories (k cal)	304.27^{a}	289.16^{c}	299.44^{b}	271.95^{d}

* Calculated on dry weight basis. Data with different superscripts in the same row are significantly different ($p< 0.05$)
\# Blends (L, LC, LM and LW) are described in **Table (1)**

(glucose) are shown in **Table 5** and illustrated by **Figure (1)**. The means of fasting glucose concentration was ranged from 10.6 ± 1.0 to 14.9 ± 1.4 mmol/ l. This range is not within the normal range of glucose concentration of the healthy human (3.5-6.5 mmol/ l). The maximum glucose concentration was measured 60 min after diet intake. After that, glucose concentrations were gradually decreased (**Fig. 1**). However, at the end of test period (120 min) the determined glucose concentrations were higher than those at the beginning of the test (0 min), except the case of LW intake. The mean of glucose concentration was 11.8 ± 1.3 mmol/ l 120 min after intake of the LW soup. Generally, all blood glucose concentrations along the test period (120 min) were near to the normal range.

The mean values of the blood glucose levels at different intervals were used to determine the incremental area under curve and then to calculate the glycemic index (GI) of lentil and lentil-based soups (**Table 5**). Generally, the GI values (ranged from 47.6 to 40.7 %) measured by the investigated human diabetic subjects indicate that all different lentil and lentil-based soups are low GI foods. This result is in agreement with the classification of diabetic diets stated by (**Wolever *et al* 1991**). However, results of the statistical analysis indicated that there are significant differences ($p<0.05$) between the obtained GI of the different prepared soups. The lowest GI (40.7%) was recorded for lentil soup which supplemented with wheat germ (LW) whereas the highest GI (47.6%) was obtained for the soup which supplemented with chickpea (LC). These differences may refer to the content of protein and dietary fiber of the lentil-based soup blends (**Table 4**). Previous studies suggested that dietary fiber reduce postprandial blood glucose responses (**Wolever *et al* 1988 and 1991**).

Table 5. Glycemic index (GI) of lentil-based soup blends and the incremental area under the curve (IAUC) of blood glucose responses

Treatments #	Blood glucose* (mmol/l)					IAUC (mmol/l min)	GI %
	0	30	60	90	120		
S	10.6±1.0	14.9±1.0	17.3±1.2	16.4±1.3	14.8±1.4	567	100
L	12.5±1.2	14.3±1.2	16.0±1.4	15.1±1.4	13.9±1.5	258	45.5 [b]
LC	14.9±1.3	17.6±1.4	18.5±1.4	16.6±1.4	16.1±1.4	270	47.6 [a]
LM	13.4±1.1	16.3±1.2	16.3±1.2	15.1±1.1	13.6±1.2	252	44.4 [c]
LW	12.4±1.1	14.3±1.1	14.8±1.2	13.7±1.3	11.8±1.3	231	40.7 [d]

* Blood glucose means of 10 subjects ± SE

\# Treatments include; 50 g glucose (S) or 50 g available carbohydrate from each blend. Blends L, LC, LM and LW) are described in **Table (1)**.

a,b,c,d There is no significant difference(P>0.05) between any this means have the same letter

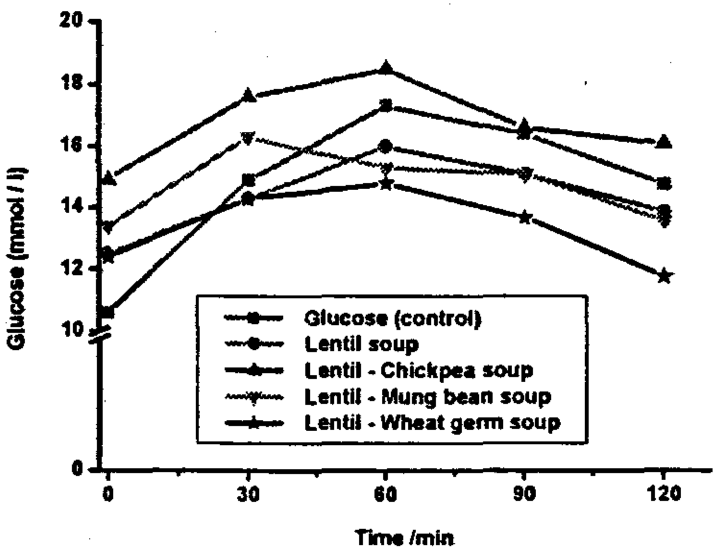

Figure 1. Means of blood glucose responses of 10 diabetic subjects to lentil soup and lentil-based soups

The mechanism of action of fiber is thought to be a reduction in the rate of absorption of dietary carbohydrate by formation of viscous gel in the small intestine. In addition to dietary fiber, supplementation of foods by others high-protein content sources may lead to reduction of the glycemic index. This may due to interaction exists between the protein and starch in foods which influences the digestibility of carbohydrate resulting in reduction of glycemic response (**Anderson *et al* 1981**).

The low GI obtained in this study may also refer to low calorie of the investigated soups. The calculated energy intakes of the prepared soups were ranged from 271.95 to 304.27 kcal (**Table 4**). This result demonstrated that all investigated soup blends are very low-calorie diets (VLCD).

This term was used by **Barnett and Garg (2000)** to describe the diet with energy intake of less than 800 kcal, which can led to improvement of plasma glucose and lipid levels. Noticeably, the current study proved that sex difference had no significant effect on the glucose responses of different studied soups (data not shown).

In conclusion, the results showed that fortification of lentil soup with wheat germ and mung beans led to improve the nutritive values and reduce the glycemic index of lentil-based soups, and can be used as a low GI food.

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التقييم البيولوجى لخلطات من شوربة العدس كغذاء لمرضى السكر

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تستخدم بعض البقوليات والحبوب للتحكم فى مستوى جلوكوز الدم لمرضى السكر. لذلك قامت هذه الدراسة بإعداد خلطات مختلفة من شوربة العدس منخفضة فى مؤشر جلوكوز الدم كغذاء خاص لمرضى السكر من النوع الثانى.

ولتحقيق هذا الهدف تم إستبدال جزء من العدس بنسبة ١٨ % بالمستخلص الخالى من

الدهن للحمص أو فول المانج أو جنين القمح والذى أدى إلى زيادة محتواها من الألياف والبروتين. وقد تم دراسة التركيب الكيماوى لهذه الخلطات والتقييم البيولوجى لها على عشرة من مرضى السكر من النوع الثانى (ثلاثة رجال و سبع إناث). وقد بينت الدراسة أن تناول هذة الخلطات من شوربة العدس المرتفعة فى محتواها من البروتين والالياف الغذائية أدى إلى انخفاض مؤشر جلوكوز الدم للمرضى موضع الدراسة حيث تراوح مؤشر جلوكوز الدم بين ٤٠,٧ و٤٧,٧%. وقد لوحظ أن هذا الانخفاض كان مصاحباً لإرتفاع محتوى الشوربة من البروتين والألياف الغذائية وقد يكون ناتج عن انخفاض السعرات الحرارية فى هذه الخلطات (٢٧١,٩٥-٣٠٤,٢٧كيلو كلورى). بصفة عامة وجد أن أفضل خلطة هى الخلطة التى أحتوت على جنين القمح تلتها الخلطة المحتوية على فول المانج حيث أدت إلى انخفاض ملحوظ فى مؤشر جلوكوز الدم من ناحية أخرى أدى التدعيم بالحمص الى انخفاض قليل فى مؤشر جلوكوز الدم بالمقارنة بالخلطات الأخرى. كذلك فقد كان مؤشر جلوكوز الدم الناتج عن تناول أى من هذة الخلطات فى حدودالاطعمة المنخفضة فى مؤشر جلوكوز الدم.

لذلك تنصح الدراسة بإستخدام خلطة شوربة العدس المحتوية على جنين القمح لمرضى السكر من النوع الثانى كغذاء خاص.

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