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BLOOD GLUCOSE RESPONSE AND GLYCEMIC INDEX OF SOME DRIED LEGUMES IN NORMAL HUMAN SUBJECTS

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ABSTRACT

Blood glucose response and glycemic Index (GI) for broad bean kernels, whole broad bean, chickpea, lentils and kidney bean in normal human subjects using glucose as standard were studied. Twenty one male normal human subjects (age 22-35 years and body mass index, BMI 22-26 kg/m²) were chosen as volunteers for this study. The subjects were divided randomly into groups where each three or four of the subjects could submit to the experiments. After 12 hours overnight fast each subject was tested for blood glucose at 0 time before given the test food or glucose standard in an amount to provide 50 g carbohydrate. Glycemic response, Incremental Area under the Curve (IAUC) and Glycemic Index (GI) were determined and calculated. The results show that there were significant (P<0.05) differences between the IAUC and GI of legumes in normal subjects. The respective GIg (GI when glucose as standard) values for the broad bean kernels, whole broad bean, chickpea, lentils and kidney bean were 66, 53, 36, 22 and 26 compared with 100 for glucose standard. The highest IAUC value (159 mmol. min/L) was resulted after the ingestion of broad bean kernels compare with the lowest value (54 mmol.min/L) after the ingestion of lentils. Comparable and similar gradient values of GIb (GI when white bread as standard) for the same legumes were resulted. It was concluded that legumes such as lentils, chickpea and kidney bean elicited very low GI, whereas whole broad bean and broad bean kernels gave medium GI. Therefore, it was suggested that the legumes which have lower GI could be used in the diet management of diabetic therapy of type II diabetes.

INTRODUCTION

It has been known that following a healthy diet can really reduce the risk of developing Non Insulin Dependent Diabetes Mellitus (NIDDM) in the future of the man. Many researches conducted numerous studies looking at the speed at which different diets affecting blood glucose response. Specifically, reducing or controlling the blood glucose response to achieve near-normal blood glucose was one of the most important goals in their strategy (Sheard *et al*., 2004). Manipulating the glycemic response of the foods was first proposed by Jenkins and his Colleagues in the early 1980s by using the parameter well known later as Glycemic index (GI) (Jenkens *et al*., 1981). GI was proposed as a concept and method of ranking foods on the basis of incremental blood glucose responses they produce for certain amount of carbohydrate (Jenkins *et al.*, 1981; Wolever *et al*., 1991 and FAO/WHO, 1997). Low GI diet has been proposed as a novel treatment of diabetes (Jenkins *et al*., 1987 and Qi *et al*., 2005). Whereas, consumption of high GI diets of carbohydrate rich foods (high glycemic load diets) was independently associated with an increased risk of developing type 2 diabetes (Foster-Powell *et al*., 2002). Therefore, in medium term studies of diabetes replacing high GI carbohydrates such as white bread and potatoes with low GI forms such as whole grain and legumes will improve glycemic control and, among person treated with insulin, will reduce hypoglycemic episodes (Willett *et al*., 2002).

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Over the past 25 years, the GI of the most common carbohydrate foods has been determined and among the foods that produce low GI includes legumes and whole cereal grains (Jenkins *et al*., 1988 and Foster-Powell and Brand-Miller, 1995).

Dry legumes have occupied an important position in human diets and represent one of the most important protein sources in foods and feed, second only to cereals (Aykroyd *et al*., 1982). In spite of limitations of utilization of legumes which associated with their low digestibility, the activity of the antinutritional substances such as trypsin inhibitors and phytates and presence of complex polysaccharides collectively representing fiber (Bhatty and Christison, 1984), fortunately, these limitations are beneficial for people with diabetes, gastrointestinal tract and heart diseases(Yoon *et al*., 1983; Thompson, 1988; Darabi *et al*., 2000 and Reddy *et al*., 2000). Regarding diabetes, the links suggested to a lower postprandial glycemia are a delay of gastric emptying and /or reduced rate of digestion and absorption of carbohydrates in the small intestine (Jenkins *et al*., 1986). Factors influencing these parameters, hence affecting the rate of starch and glucose uptake, are the nature of the starch, starch-nutrient interactions, presence of dietary fiber and antinutrients (Wursch, 1989). Because of the nature of the legumes a variety of methods are used for processing, cooking, baking and of the way they use such as water availability and soaking, temperature and length of cooking even legume to legume in different parts of the world (Aykroyd *et al*., 1982). Therefore, different GI values for different kind of legumes were resulted (Darabi *et al*., 2000). The aim of this study was conducted to determine the glycemic response of some legumes traditionally consume by human such as broad bean, chickpea, lentils and kidney bean which have controversial link with diet management of diabetic patients.

MATERIALS AND METHODS

Foods: Four different legumes, broad bean (*Vicia faba*), chickpea (*Cicer arietinum*) lentils (*Lens esculenta*) and kidney bean (*Phaseolus vulgaris*) were used in this study. All the legumes were purchased from local market in Mosul City- Iraq. Seeds were sorted from dirt and stones and washed with tap water then dried in Cabinet dryer with hot air at 55°C for 48 hours and packed in polyethylene sacs until next step. Broad bean was used and cooked in two ways; as kernels without cortex and a whole seeds with their cortex.

Chemical Analysis: Approximate analysis was performed to determine the chemical composition of raw materials of the legumes (Table 1). Moisture was determined according to the method of AOAC (1980) by using rapid moisture tester made by

Table (1): Chemical composition of some legumes on dry weight bases (g/100g)

Foods	Components				
	Protein	Fat	Fiber	Ash	Carbohydrate*
Broad bean, kernels	٣٢.٤	1.3	1.2	2.6	62.5
Whole broad bean	29.16	1.64	7.34	٤.٦	57.3
Chickpea	22.97	5.40	3.63	2.68	65.3
Lentils	28.59	1.50	2.00	2.40	65.5
Kidney bean	24.79	1.98	5.29	4.10	63.8

*by difference. The numbers are average of three samples.

Brabander, Germany at 105°C until constant weight. Protein was determined according to the procedures mentioned by Pearson (1973) using Macrokjeldahl method. Fat was determined according to the procedures mentioned by Pearson (1976) using Soxhlet method. Crude fiber was determined according to the procedures mentioned by Pearson (1973). Ash determination was performed according to the method of AOAC (1980).

Determination of Gelatinization: Degree of temperature of gelatinization for broad bean, chickpea, lentils and kidney bean was measure using Viscograph according to the method of AACC (1976) (Table 2).

Apparent and Total Amylose Determination: Apparent amylose was determined according to the method of Morrison *et al.* (1988) using Urea Dimethyl sulphoxide solution. Apparent amylose was estimated by spectrophotometer at 630 nm and using the following equation:

Apparent Amylose % = 29.41 X Blue value – 5.23

Whereas Total Amylose was determined using Urea Dimethyl Solphoxide solution after removing the fat materials by Ethyl alcohol and reading at 630 nm then using the same equation (Table 2).

Table (2): Amylose and amylopectin content of the starch and gelatinization temperature of some legumes

Food	Apparent amylose %	Amylopectin* %	Total amylose %	Amylopectin* %	Gelatinization temperature, C°
Broad bean	28.3 b	71.8 a	32.1 bc	67.9 a	72.5 b
Chickpea	28.8 b	71.2 a	31.5 c	48.3 b	73.5 b
Lentils	36.6 a	63.7 b	39.1 a	61.4 ab	74.0 b
Kidney bean	34.2 a	65.8 b	35.5 b	64.5 a	83.0 a

* By difference. Same letters in the column indicates that there is no significant difference ($p < 0.05$).

Ready to eat broad bean, chickpea, lentils and kidney bean: Certain amounts of legumes were weighted as shown in Table 3 to have 50 g carbohydrates in the final consumed foods. The weighed broad bean, chickpea and kidney bean were soaked with adequate amount of water for 12 hours. The soaked legumes were cooked with 2 % NaCl for three hours. In case of lentils, it was cooked with adequate water and 2 % NaCl for 40 min without soaking. The water of cooking should be kept with the solid materials to avoid any lost of soluble starch and protein. All ready to eat legumes diets were freshly prepared when they consumed to perform the experiment.

Table (3): Components and composition of diets prepared for blood glucose response.

Foods	Weight of food before cooking, g	Components, g					Weight of consumed food, g
		CHO	Protein	Fat	Fiber	Ash	
Broad bean, kernels	80	50	25.9	1.04	0.96	2.08	248
Whole broad bean, cortical	87.3	50	25.5	1.43	6.41	4.02	267
Chickpea	76.6	50	17.6	4.15	2.79	2.05	212
Lentils	76.3	50	21.8	1.16	1.53	1.85	218
Kidney bean	78.4	50	19.4	1.55	4.15	3.22	215

The numbers are average of three samples.

Subjects: Twenty one normal male human subjects (age 22-35 years and Body Mass Index, BMI 22-26 kg/m²) were chosen as volunteers in this study. The subjects were randomly divided into groups where each three or four of the subjects could submit to the experiment. After 12 hours overnight fast the subject was tested for blood glucose at zero time before given in an amount of test food containing 50 g carbohydrate. Blood glucose was determined after 15, 30, 45, 60, 90, and 120 minutes. The same method was performed by the subject by ingestion 50 g of glucose dissolved in 250 ml water. **Measurement of Blood Glucose Response:** Blood glucose was determined by using glucose tester Device made by Johnson and Johnson Co., Lifescon, USA. Blood samples were taken from subject finger using finger prick capillary. Glycemic Index (GI) for each diet was determined by calculation of Incremental Area Under two hours of blood glucose response or Curve (IAUC) for each diet and compared with the IAUC for glucose solution standard according to the method of Jenkins *et al.* (1981); Wolever and Jenkins (1986) and Wolever *et al.* (1991) which also reported by FAO/WHO (1997) using the following equation:

$$GI = \frac{\text{Incremental Area Under 2h blood glucose Curve for food}}{\text{Incremental Area Under 2h blood glucose Curve for glucose or white bread}} \times 100$$

Statistical Analysis: The complete randomized design (CRD) was used. Statistical difference was determined using Duncan's multiple range test at ($p<0.05$) by SAS Version (1989).

RESULTS AND DISCUSSION

Blood glucose response of broad bean, chickpea, lentils and kidney bean in normal subject is shown in Figure 1 and Table 4. The results show that there was a tardy graduate increase in blood glucose responses curves for broad bean without cortex and with it, chickpea and lentils to reach the highest mean values (5.90, 5.63, 6.10 and 4.66 mmol/L, respectively) 45 or 60 min after the beginning of the ingestion of the diets. There was no significant (P<0.05) differences among the highest mean values for the above legumes. Whereas, there was a sharp increase in blood glucose response curve for kidney bean to reach the highest mean value (5.90 mmol/L) 15 min after the ingestion of the diets. Similarly, the results show that the response was increased high enough to reach the highest mean value of 7.16 mmol/L 30 min after the beginning of the ingestion of the glucose standard. The glucose response then fell gradually to reach the values of 6.33 mmol/L 60 min after the ingestion of glucose solution and to be close enough with the values of other legumes. For most of the diets, the blood glucose response curves were fell steady and gradually 60 min after the ingestion of all diets. The glucose levels then remained at approximately their baseline for the remainder of the tow hours. The IAUC and GI for all legumes compared with glucose standard were calculated (Table 4). The data show that significant (P<0.05) variable IAUC values for the ingested legumes by subjects were resulted. The respective IAUC values for the broad bean kernels, whole broad bean, chickpea, lentils and kidney bean were 159, 128, 87, 54 and 63 mmol.min/L compared with 242 mmol.min/L for glucose standard. The highest IAUC value (159 mmol. min/L) was resulted after the ingestion of broad bean kernels compared with the lowest value (54 mmol.min/L) after the ingestion of lentils. Data in Table 4 show that the IAUC for broad bean was increased with decortication of seeds. Similarly, significant (P<0.05) variable GI values for ingested legumes by subjects were shown (Table 4). The corresponding GIg values for broad bean kernels, whole broad bean, chickpea, lentils and kidney bean were 66, 53, 36, 22 and 26 compared with 100 for glucose standard. By calculation, similar and comparable but higher GIb values for the legumes compared with white bread were shown in the Table 4. The results show that the highest GIb value (94) was given after the ingestion of broad bean kernels compared with lowest value (31) for ingestion of lentils. Comparable and similar results of GI of lentils, broad bean, kidney bean and chickpea in diabetes were found or reviewed by several studies (Dilwari *et al*.,

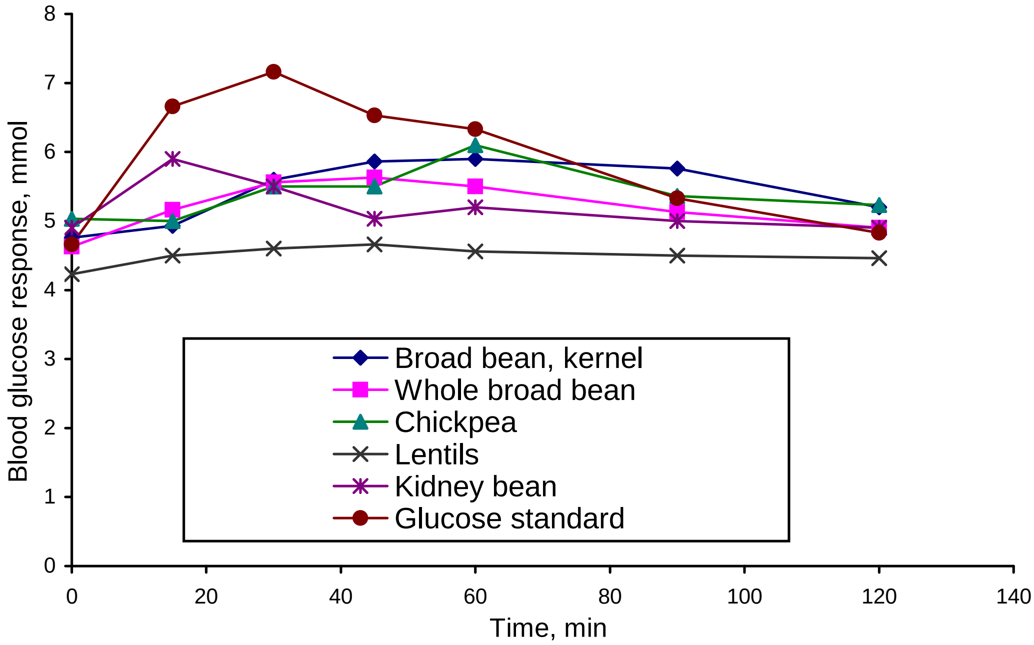

Fig.1:Blood glucose response of some legume for normal human subjects

Table 4: Blood glucose response, Incremental Area Under Curve (IAUC) and Glycemic index (GI) of some legumes for normal subjects.

Food	IAUC mmol.min/L	GIg	GIb
Broad bean Kernels	159 b	66 b	93
Whole broad bean	128 bc	53 c	75
Chickpea	87 cd	36 d	51
Lentils	54 d	22 e	31
Kidney bean	63 d	26 de	37
Glucose standard	242 a	100 a	141

Same letters in the column indicate that there is no significant difference (p<0.05).
GIg Glycemic index when the standard is glucose solution. (GIg X 0.7 Foster-Powell and Brand-Miller, 1995).
GIg Glycemic index when the standard is White bread. (GIg X 1.41 Foster-Powell and Brand-Miller, 1995).
The numbers are means of 3 values for 3 subjects (triplicate).

1981; Jenkins *et al.*, 1981; Bornet *et al.*, 1987; Wolever *et al.*, 1987a and 1987b; Granfeldt et al., 1992; Foster-Powell and Brand-Miller 1995 and Darabi *et al.*, 2000).

Differences in glucose responses for different foods and for the same group of food may be attributed to various factors such as component and the nature of the carbohydrates, dietary fiber content, method or extent of food processing and antinutritional substances as an inhibitors of enzymatic digestion (Jenkins *et al.*, 1978; Thorne *et al.*, 1983; Yoon *et al.*, 1983; Tovar *et* *al*., 1992; Bjorck *et al*., 1994; Darabi, *et al*., 2000). The GI of dried legumes has been found to be the lowest among starchy foods (Bornet *et al*., 1989 and Tovar *et al*., 1992). Darabi *et al.* (2000) mentioned that the nature of the starch in the legumes may influence their starch digestibility. It has been known that high amylose starch has been shown to be digested far more slowly than the high amylopectin starch. In mixed meal, when starches with different amylose-amylopectin ratios were incorporated into a meal, the one with the high amylopectin starch showed higher GI than that of the low amylopectin starch for normal and diabetic rats (Kabir *et al*., 1998). Reference to Table 2, the amylose contents of the legumes were higher (28-36 %) compared with lower percent (15-30 %) for most of the other carbohydrate foods such as cereals (Behall *et al.*, 1988 and Bornet *et al.*, 1987). Table 2 also shows that the percent of the amylose was increased at the expense of the amylopectin in the legumes. Therefore, higher amylose vs amylopectin percent in the foods decreases the digestion of the total starch and consequence decreasing the GI values (Behall *et al*., 1988 and 1989; Behall and Howe 1995; Bornet *et al*., 1987. Weaststrate and Van Amelsvoort, 1992). Because lentils possess high percent of amylose (36.6 %) and low percent of amylopectin (63.7 %) among the analyzed legumes it may be elicited the lowest IAUC (31.5) and GI (22.2). Concerning to this subject, comparable results were shown with kidney beans which elicited the highest degree of gelatinization (83.0 °C) (Table2 and 4). However, in processing of legumes like broad bean and kidney bean, more time for cooking is required than dehulled seeds which require more time for heat and water to penetrate the hulled seeds and gelatinize the starch (Darabi *et al.*, 2000). Other factors such as protein, fat, fiber and method of preparation determine the GI of the foods (Bjorck *et al*., 1994; Wolever et al., 1991 and Welch *et al*., 1987). The chemical composition of the legumes was shown in Table 1 and 3. Data show that they are rich sources of protein and fibers among human foods. Previously, there was an indication that addition of fat and protein might reduce the glycemic impact of challenges with single carbohydrate foods (Collier and O'Dea 1983 and Collier *et al*., 1984). However, Franz (2000) and Gannon *et al*. (2001) stated that protein does not affect the absorption of carbohydrates or the glucose response peak whereas; fat delays the peak but not the total glucose response. The same researchers suggested that there are some indications that the long-term consumption of high fat and high protein diets may induce insulin resistance. Usami *et al*. (1982) found that concentration of plasma glucose and insulin were increased after consumption of high protein diets by long term fasting rats compared with standard diet.

In addition to be a good source of protein, legumes in general contain more fiber than other starchy seeds. Their relative high fiber content is evident from Table 1. The data show that broad bean and kidney bean are fairly rich of fiber (they contain 7.34 and 5.29 % , respectively). It was obvious that fiber content appears to make differences in the resulted IAUC and GI of the legumes (Table 4). Our results show that with decortications of whole broad bean the fiber content of the seeds decreased from 7.34 to 1.2 % fiber as a percent in the kernels. By this process, the GI of the broad bean was increased from 53 for whole broad bean to 66 for broad bean kernels. Removal of the hull from the whole bean flour increased the rate of starch digestion, while its readdition to the dehalled flour decreased the rate to that of the whole bean flour (Thompson, 1988). As the fibers are constituents of the plant cell walls, it can be supposed that the fiber content of a particular food might influence the rate of carbohydrate digestion through the resistance induced by the cell wall to swelling of the starch granule during cooking (Wursch *et al*., 1986). Epidemiological studies have consistently shown a beneficial effect of fiber, in reducing the risk of diabetes (Meyer *et al*., 2000). Precisely; several evidences suggest that dietary fibers may play a key role in the regulation of circulating insulin levels. In some way, they reduce insulin secretion by slowing the rate of nutrient absorption following ingestion of the diet (Potter *et al*., 1981 and Jenkins and Jenkins, 1987). Similar findings were conducted by Anderson and Ward (1978) in which high carbohydrate high fiber diets, composed mainly of vegetables and seeds, have been used to reduce both the postprandial hyperglycemia and the insulin or antidiabetic agent requirements of diabetics. However, Trappy *et al*. (1986) suggested that the slow carbohydrate property of legumes is not due to their fiber content, but might be related to the histological structure of the seed. Further, fiber in general helps to increase the rate at which food is passed through the digestive tract.

From Table 4 the results show that broad bean elicited high GI values (66 and 53 for broad bean kernels and whole broad bean respectively) compared with other legumes (22, 26 and 36 for lentils, kidney bean and chickpea, respectively). Darabi *et al*. (2000) found the reason of that in which broad bean is a good source of calcium, which is known to catalyze amylase activity which influence and increase starch hydrolysis, so higher blood glucose response in comparison with other legumes. However, phytic acid which is high in legumes may reversely affect this direction by restriction of calcium activity. Literature showed that removal of endogenous phytic acid from navy beans increased the in-vitro rate of starch digestion and the blood glucose response, while readdition of the phytic acid to the dephytinized flour produced the opposite effect (Thompson, 1988). Furthermore, legumes are also rich source of many antinutrients such as trypsin inhibiotor, lectins, saponins, uronic acid and tannins which are known to interfere or restrict starch digestibility (Thorne *et al*., 1983; Yoon *et al*., 1983; Thompson 1988 and Darabi *et al*., 2000). The legumes which contained the highest concentrations of phytic acid, lectins and tannins were digested the slowest and produced the flattest blood glucose response (Thompson 1988)

It was concluded that legumes such as lentils, chickpea and kidney bean elicited very low GI, whereas whole broad bean and broad bean kernels gave medium GI. Therefore, it was suggested that the legumes which have lower GI could be used in the diet management of diabetic therapy of type II diabetes.

استجابة كلوكوز الدم والمؤشر الكلوكوزي لبعض البقوليات الجافة لدى الأشخاص الطبيعيين من الذكور

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تم دراسة استجابة كلوكوزالدم وتقدير المؤشر الكلوكوزي لبعض أنواع البقوليات الجافة وهي لب الباقلاء والباقلاء الكاملة والحمص والعدس والفاصوليا لدى الأشخاص الطبيعيين من الذكور واستخدام سكر الكلوكوز كمعيار قياسي (Standard). شارك في هذه الدراسة ١٥ شخص من الذكور الطبيعيين تراوحت أعمارهم بين ٢٢-٣٥ سنة وتراوح مؤشر كتلة ألجسم (Body Mass Index, BMI) بين ٢٢-٢٦ كغم/م². تم تقسيمهم إلى مجاميع بحيث كان هناك ثلاث أو أربع أشخاص لكل قياس. تم قياس سكر الدم في الوقت صفر بعد مدة ١٢ ساعة صوم عبر الليل قبل إعطائهم الأغذية والتي احتوت على ٥٠ غم كاربوهايدرات وكذلك محلول سكر الكلوكوز. بعدها تم قياسه في الوقت ١٥ و٣٠ و٤٥ و٦٠ و٩٠ و١٢٠ دقيقة ثم تم حساب كل من المساحة المضافة تحت المنحنى IAUC والمؤشر الكلوكوزي GI للبقوليات وكذلك سكر الكلوكوز. أشارت النتائج إلى أن هناك فرق معنوي (P<0.05) بين قيم المساحة المضافة تحت المنحنى والمؤشر الكلوكوزي للبقوليات . كانت قيم المؤشر الكلوكوزي لكل من لب الباقلاء والباقلاء الكاملة والحمص والعدس والفاصوليا لدى الأشخاص الطبيعيين من الذكور هي ٦٦ و ٥٣ و ٣٦و ٢٢ و ٢٦ على التوالي. وكانت أعلى قيمة للمساحة المضافة تحت المنحنى هي ١٥٩ ملي مول. دقيقة/ ليتر بعد تناول لب الباقلاء واقل قيمة لها هي ٥٤ ملي مول. دقيقة/ليتر بعد تناول العدس. كانت قيم المؤشر الكلوكوزي مقارنة بالخبز الأبيض متشابهة ومتوافقة ومتدرجة مع قيم المؤشرالكلوكوزي المقرون بالكلوكوز. وكان استنتاجنا هو أن المؤشر الكلوكوزي لكل من العدس والفاصوليا والحمص منخفضا بينما كان المؤشر الكلوكوزي لكل من لب الباقلاء والباقلاء الكاملة ضمن القيم المتوسطة. وكان المقترح هو أنه يمكن استخدام كل من العدس والفاصوليا والحمص في برنامج تغذية المصابين بداء السكر من نوع الثاني Type II diabetes.

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