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Glycemic Responses of Food Formulations Based on White Rice and White Bean

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Abstract

The management of diabetes mellitus is based on lifestyle and dietary measures suggesting the consumption of foods with a low glycemic index. The present study was conducted in order to propose food formulas based on white rice and white beans resulting in a lower glycemic response. For this, food formulations based on these foods were first made, in particular the formulation [75% white rice + 25% white beans] and the formulation [50% rice + 50% white beans]. Then, the biochemical composition of white rice, white bean and these two formulations was determined by the usual methods. Finally, their glycemic responses over 120 minutes were studied by the FAO/WHO 1998 method. The results showed that white rice [100% white rice] had the highest carbohydrate content (54.61%) followed respectively by the formulation [75% white rice + 25% white bean] (45.69%), the white bean [100% white bean] (29.1%) and the formulation [50% white rice + 50% white bean] (26.16%). In terms of glycemic responses, the formulation [50% white rice + 50% white beans] presented the best evolution with a lower peak (6.041 mmol/L) observed at $T45_{min}$ and a lower postprandial glycemia (4.872 mmol/L) at $T120_{min}$. An increase in the proportion of beans is therefore recommended as it may suggest a beneficial metabolic effect.

Keywords

White Rice, White Bean, Food Formulation, Glycemic Response

1. Introduction

Diabetes represents a real public health problem on a global scale and more particularly in developing countries because of its morbidity and mortality and the high cost of its treatment [1]. Lifestyle and dietary measures are very important in the management of diabetes mellitus because they constitute the basis of the treatment motivating the consumption of foods with a low glycemic index (GI) [2]. As part of developing low-GI diets, legumes have been evaluated on markers of glycemic control in both diabetic and non-diabetic individuals and shown substantial benefit [3]. Beans are considered one of the major energy-providing legumes and an important source of protein in developing countries [4] [5]. In Côte d'Ivoire, rice has become the main food of the population, both in urban and rural areas [6] due to the change in people's eating habits. Given the number of diabetics, the formulation of low glycemic index recipes from local foods (cereals and legumes) would be an innovation in nutrition and would improve the management of diabetic subjects in Côte d'Ivoire. It is in this perspective that this work was undertaken with the general objective of proposing food formulas based on white rice and white beans that can lead to a lower glycemic response.

2. Material and Method

2.1. Vegetable Material

The plant material used in this work consists of white rice (*Oryza sativa*) and white bean (*Phaseolus vulgaris*). The seeds of the white bean and the local white rice were purchased at the market in the commune of Abobo (Abidjan, Ivory Coast).

2.2. Methods

2.2.1. Framework of the Study

The food formulations and the study of the glycemic responses of the dishes studied took place at NANGUI ABROGOUA University.

2.2.2. Development of the Different Recipes Studied

- White rice: The grains of rice were sorted, washed and then cooked for 20 minutes at the rate of a glass of rice in 1 and a half glasses of water.
- White bean: The beans of the bean were sorted, washed and then soaked for three hours. After soaking the grains were drained, cooked for 45 min at the rate of a glass of the bean in 2 and a half glasses of water to obtain the cooked bean.
- Recipe [75% rice + 25% beans]: White rice and white beans were cooked separately then mixed according to the proportions. So for 100 g of recipe, we bring 75 g of white rice and 25 g of white beans.
- Recipe [50% rice and 50% beans]: White rice and white beans were cooked separately then mixed according to the proportions. So for 100 g of recipe we bring 50 g of white rice and 50 g of white beans.

At the end of cooking, each recipe was dried in an oven at 45˚C for 48 hours, ground using a blender and then sieved to obtain different flours for the analyzes of biochemical parameters.

2.2.3. Physicochemical Analysis of Flours

Dry matter and ash content were determined by the AOAC method [7] [8]. The protein content was determined using the Kjeldahl method [7]. Fat content was determined using the Soxhlet extraction method using hexane as the solvent [7] (AOAC, 1990). The crude fiber content was determined according to the Weende method [7]. The carbohydrate content was determined by calculation as described by the FAO/WHO [9]. The energy value of formulated foods was determined using the coefficients of Merril and Watt (1975) adopted by the FAO [9].

2.2.4. Glycemic Response of Foods

Study participants had normal blood sugar levels, were free from diabetes, had no risk factors for diabetes mellitus, and were not taking any medication. The principle of measuring the glycemic response of foods is based on the consumption by the subjects of 50 g of anhydrous glucose (reference food or test food) and 50 g of available carbohydrates provided by the foods to be tested and the monitoring of the change in glycaemia over 120 minutes [9]. The different recipes studied were prepared according to the methodology described above. The quantity of foods to be tested, calculated on the basis of an intake of 50 g of available carbohydrates, is based on the difference between the proportion of total carbohydrates and total crude fiber [10]. The test began by taking the subjects' fasting blood glucose levels, corresponding to the blood glucose at T0, 5 minutes after their arrival. In fact, all the subjects were previously subjected to a 12-hour fast. Only one food was tested per day therefore five (5) days were necessary to carry out this study. Following the sampling of the fasting glycaemia of each subject, each of them consumed the food of the day. The duration of consumption was 3 to 5 minutes depending on the subject. Postprandial glycaemia was determined over 2 hours, including every 15 minutes during the 1st hour then every 30 minutes during the 2nd hour (15 min, 30 min, 45 min, 60 min, 90 min, 120 min).

2.2.5. Statistical Analysis of Data

The statistical analysis of data from the study of glycemic responses covers the calculation of the mean affected by the standard deviation. All the measurements were carried out at least three times depending on the parameter studied. Statistical differences between samples and measured parameters were checked with ANOVA using XLSTAT software version 2016.02.27444. The comparison of means was made using the Student Test (comparison of two means) and Duncan (comparison of more than two means) at the significance level fixed at 5%.

3. Results

- Biochemical characteristics of the foods studied

The biochemical characteristics of the foods studied (local white rice, white beans, local white rice enriched with 25% then 50% white beans) are presented in **Table 1**.

White rice (R1) has the highest carbohydrate content (54.61%) followed

Table 1. Macronutrient content and energy value of the foods studied.

Settings biochemicals	Contents (g/100g of DM)			
	R1	HB	HR25	HB50
Humidity	35.16 ± 0.01[a]	40.72 ± 0.01[b]	59.28 ± 1[b]	57 ± 1[b]
DM	64.84 ± 0.01[a]	40 ± 0.01[b]	60 ± 1[b]	63 ± 1[b]
Proteins	7.32 ± 0.22[d]	25.37 ± 0.05[a]	11.04 ± 0.002[c]	14.67 ± 0.14[b]
Lipids	0.85 ± 0.06[c]	2.61 ± 0.12[a]	0.92 ± 0.08[c]	1.19 ± 0.02[b]
Ashes	2.06 ± 0.03[a]	2.20 ± 0.03[a]	1.63 ± 0.02[b]	0.98 ± 0.15[c]
Total carbohydrates	54.61 ± 0.01[a]	29.1 ± 0.9[c]	45.69 ± 0.01[b]	26.16 ± 0.01[d]
Fibers	1.54 ± 0.22[d]	6.32 ± 0.34[a]	2.56 ± 0.33[c]	3.18 ± 0.1[b]
EV	255.37 ± 1.29[b]	241.37 ± 0.68[a]	235.2 ± 1.25[d]	174.03 ± 1.24[c]

The values correspond to the mean ± standard deviation of three independent measurements (n = 3). Values followed by different letters on the same line are statistically different ($p < 0.05$). R1 = Local white rice (100%); HB = White bean seeds (100%); HR25 = Local white rice (75%) + white bean seeds (25%); HB50 = Local white rice (50%) + white bean seeds (50%); EV = Energy value; DM = Dry matter.

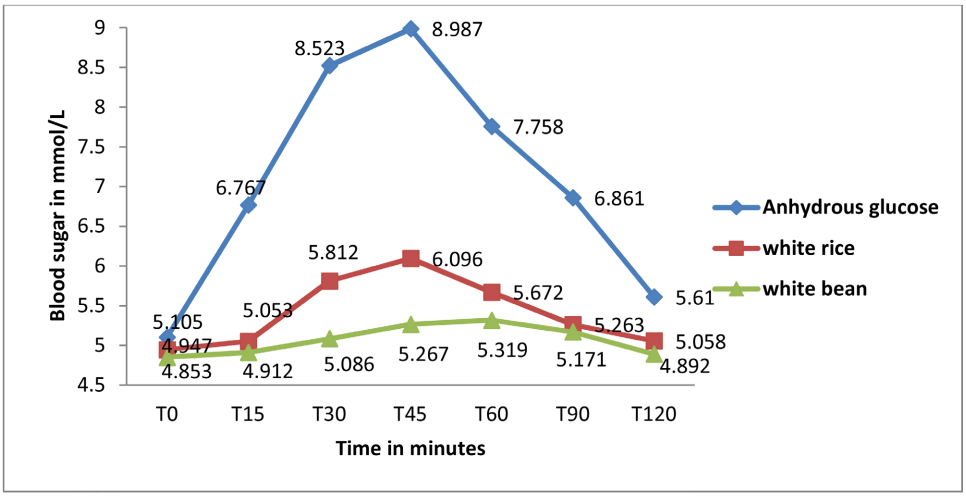

Figure 1. Glycemic responses after consumption of anhydrous glucose, white rice and white bean.

respectively by the formulation [75% white rice + 25% white bean] (HR25: 45.69%), white bean (HB: 29.1%) and formulation [50% white rice + 50% white bean] (HB50: 26.16%). The fiber content of the formulated foods gradually increased with the proportion of beans present in the formulation. It was 2.56% for the formulation [75% white rice + 25% white bean] and 3.18% for the formulation [50% white rice + 50% white bean].

- Glycemic responses of the foods tested (Figure 1)

A lower peak (5.319 mmol/L) observed at $T60_{min}$ and a lower postprandial glycaemia (4.892 mmol/L) at $T120_{min}$ are observed for the white bean.

A lower peak (6.041 mmol/L) observed at $T45_{min}$ and a lower postprandial glycaemia (4.872 mmol/L) at $T120_{min}$ are observed for the formulation [50% white rice + 50% white bean] (Figure 2).

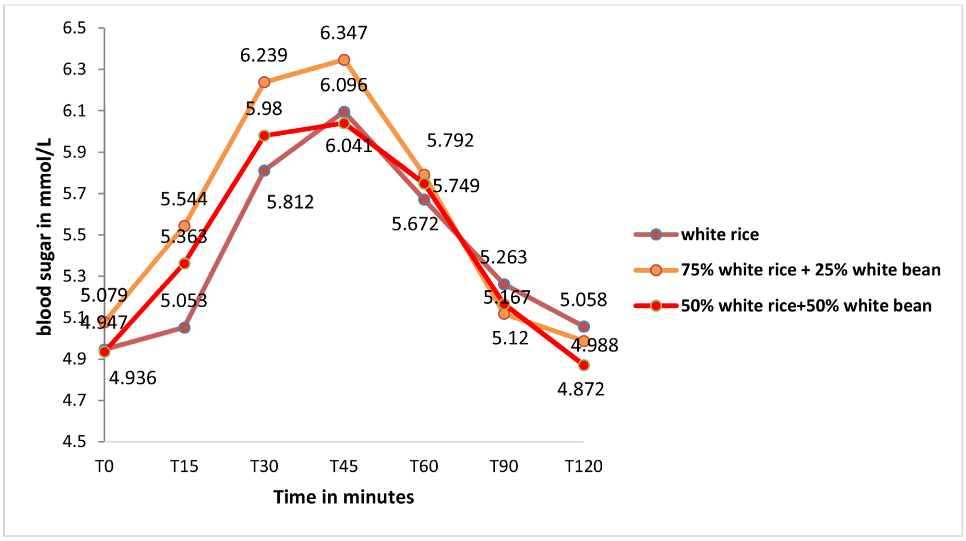

Figure 2. Glycemic responses after consumption of white rice, formulation [75% white rice + 25% white bean] and formulation [50% white rice + 50% white bean].

4. Discussion

- **Biochemical characteristics of the foods studied**

Physico-chemical analyzes of foods have shown that different foods are very rich in carbohydrates. White rice had the highest carbohydrate content (54.61%) followed respectively by the formulation [75% white rice + 25% white bean] (45.69%), white bean [100% white bean] (29.1%) and formulation [50% white rice + 50% white beans] (26.16%). There was a significant difference between the carbohydrate content of the different foods studied. Indeed, rice being a reserve organ, its albumen is made up of cells containing a large number of starch storage organelles [11]. This explains its high carbohydrate content. However, when white rice is combined with white beans, its carbohydrate content decreases as the proportion of beans is higher in the mixture. This could be explained by the fact that the white bean having a high protein content (25.37%), the more a large amount of beans is added to the rice the more the protein content of the formulation also increases and could have an impact on the amount of carbohydrates present in the mixture.

The fiber content of the foods studied varies between 1.54% and 6.32%. White bean has the highest content (6.32%) followed in decreasing order by the formulation (50% white rice + 50% white bean) (3.18%), the formulation (75% white rice + 25 % white bean) (2.56%) and white rice (1.54%). The fiber content determines the proportion of carbohydrates available in the food. At equal carbohydrate content, the more a food is rich in dietary fiber, the less this food will have available carbohydrates. Thus, dietary fibers prevent constipation obesity, hypercholesterolemia. They reduce postprandial hyperglycaemia and glucose intolerance [12]. Consuming fiber-rich foods would therefore have a beneficial effect on health.

White beans have a higher fat content (2.61%) than white rice (0.85%). Thus the more beans are associated with rice (from 25% to 50%) the more the lipid content of the formulation increases (from 0.92% to 1.19%). This increase in lipid content could be beneficial for health because legumes contain polyunsaturated fatty acids which have a protective role in the body [13]. In addition, a high fat content would promote the absorption of minerals and fat-soluble vitamins [14]. Foods combining white beans and white rice have a higher energy value compared to that of white rice. This could be explained by the fact that foods contain high levels of lipids. Indeed, foods that combine high levels of fat and protein yield the highest energy values [15].

- **Glycemic Responses of the Foods Studied**

Analysis of glycemic responses after consumption of anhydrous glucose, white rice, white bean, formulation (50% white rice + 50% white bean) and formulation (75% white rice + 25% white bean) showed an increase in blood glucose in all subjects.

During a meal, food is ingested and this leads to higher blood sugar levels during the time of digestion (postprandial period). The increase in blood sugar levels is due to the assimilation and digestion of ingested sugars. In addition, the addition of these sugars with foods that contain dietary fiber have significant effects on the evolution of blood sugar [16]. White beans had the highest fiber content of any food. This explains why the amplitude of the curve of evolution of glycaemia after consumption of beans is the lowest. However, the evolution curve of the glycaemias of the formulations (white bean-white rice) is higher than that of white rice during the first hour but during the second hour the glycaemias of the subjects having consumed the different formulations drop below that of the white rice. For the formulation (50% white rice + 50% white beans), blood sugar levels at the 120th minute are even lower than fasting blood sugar levels. This significant drop in the blood sugar of the subjects who consumed the formulations (white rice – white bean) could be explained by the significant presence of proteins and fibers in the various mixtures. Many studies indicate an improvement in glycemic control and hemoglobin glycation (HbA1c), in people with T1D or T2D who consumed more fiber. A meta-analysis carried out over a period of 8 - 16 weeks concluded that the consumption of foods rich in dietary fiber or supplemented with soluble fiber reduced the concentrations of HbA1c and fasting plasma glucose in diabetics [17].

The results also showed that the peaks of the glycemic responses of the foods studied and of the test food (anhydrous glucose) all appear at the 45th minute after their consumption, except that of the white bean which appears at the 60th minute with the highest peak low. The blood sugar peaks observed with different amplitudes between dietary fiber sources may be justified by the fact that blood sugar responses are related to the amount of fiber each food contains. The higher the dietary fiber content in a food, the lower its blood sugar.

Comparing formulated foods to white rice, the formulation (75% white rice + 25% white bean) has the highest blood sugar peak (6.347 mmol/l) followed by white rice (6.096 mmol/l) and formulation (50% white rice + 50% white beans)

(6.041 mmol/l). On the other hand, at T120, white rice has the highest glycaemia (5.058 mmol/l) followed by the formulation (75% white rice + 25% white beans) (4.988 mmol/l) and the formulation (50% white rice + 50% white bean) (4.872 mmol/l). Pulses given alone or as part of low glycemic index or high fiber diets improve key markers of glycemic control. Their consumption is therefore recommended to optimize glycemic control in type 2 diabetes [3].

5. Conclusion

The nutritional support of diabetic patients constitutes the basis of the treatment of diabetic disease. The formulation of local dishes, at a lower cost, with a lower glycemic response could improve their glycemic control and contribute to reducing the incidence of complications. It would therefore be preferable, within the framework of a dietary prescription, to favor the consumption of white rice associated with white beans in order to reduce the risk of occurrence of metabolic diseases such as diabetes and to allow diabetic patients to consume foods with a lower glycemic response.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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