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Comparative Study of Glycemic Responses of Carbohydrate Foods Consumed with a Food Rich in Dietaryfiber: Raw Vegetables, Cooked Leafy Vegetables or Fruits

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Abstract Increasingly, diabetes, which is a metabolic disease, constitutes a major public health problem. A balanced diet and regular consumption of foods rich in dietary fiber such as raw vegetables, leafy vegetables and fruits are among the characteristics of the new eating habits of diabetic patients for better care. The objective of this study was to carry out a comparative study of glycemic responses (GR) after consumption of these different foods rich in dietary fiber. To do this, a food consumption survey was carried out among the populations of Abidjan to find the most consumed raw vegetables, cooked leafy vegetables and fruits. Then, the glycemic responses of a carbohydrate food (rice) associated with one of these foods rich in dietary fiber were studied. The data obtained were analyzed using SPSS version 22 software at the 5% threshold. The results showed that the most consumed foods rich in dietary fiber were lettuce salad (44.27%) and raw vegetable salad (38.21%) for raw vegetables, potato leaf sauces (67.34%) and spinach leaves (22.92%) for leafy vegetables, orange (36.33%) and sweet banana (33.26%) for fruits. The glycemic responses obtained after consumption of white rice + fruits (orange, sweet banana) are the highest, followed by those after consumption of white rice + raw vegetables (raw vegetables, lettuce salad) then white rice + leaf sauces (leaves potatoes, spinach leaves).

Keywords: *dietary fiber, hypoglycemic effect, glycemic response, diabetes*

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1. Introduction

One of the fundamental roles of food is to provide consumers with nutrients to cover their nutritional needs but also to give them a feeling of satisfaction or even well-being, through hedonic vectors such as taste [1]. However, when this diet is unbalanced in quantity and quality over the long term, it can lead to certain metabolic pathologies such as obesity, high blood pressure but also diabetes. Several research studies have shown that a diet rich in dietary fiber is recognized as favorable to good health for both healthy subjects and those affected by metabolic diseases, because it facilitates digestive transit and helps with homeostasis sugars, cholesterol and fats [2]. However, the consumption of foods rich in dietary fiber by populations is generally lower than the recommendations of international health organizations which place them on average at 30 g/day. However, in diabetic patients, postprandial hyperglycemia which occurs very regularly due, among other things, to the consumption of foods with a high glycemic index and/or foods low in dietary fiber, contributes to aggravating the metabolic imbalance and contributes, in a way significant contribution to the increase in glycated hemoglobin levels [3]. Which subsequently increases the risk of complications such as diseases, cardiovascular diseases, infections, etc. and worsens one's state of health.

During the start of the treatment of the diabetic patient, well before medication prescriptions, hygienic and dietary measures which revolve around a good diet and the regular practice of physical activity, are recommended because they play a role crucial in the control of postprandial hyperglycemia [4]. The recommended diet in particular is that which favors the selection of foods with a low or medium glycemic index and the regular consumption of foods rich in fiber [5]. Foods such as raw vegetables, leafy vegetables and fruits, which are among the foods rich in dietary fiber, effectively help avoid recurrent postprandial hyperglycemia. Which of these foods best contribute to balancing the consumer's

glycemic responses?

The general objective of this work was to carry out a comparative study of glycemic responses after consumption of a carbohydrate food (rice) associated with foods rich in dietary fiber. For this, the raw vegetables, leafy vegetables and fruits most consumed by the populations were sought through a dietary survey then the glycemic responses of rice associated with one of the foods rich in dietary fiber were studied in the healthy subjects.

2. Material and Methods

2.1. Biological Material

The biological material used consisted of

- a carbohydrate food: rice (*Oryza sativa*)
- raw vegetables: vegetable salad and lettuce salad, composed of lettuce (*Lactuca sativa*), onion (*Allium cepa*), tomato (*Solanum lycopersicum*), carrot (*Daucus carota*), cucumber (*Cucumis sativus*),
- cooked leafy vegetables: spinach leaf sauce (*Sapinacia olenacea*), potato leaf sauce (*Ipomoea batatas*)
- fruit: sweet banana (*Musa paradisiaca*), orange (*Citrus sinensis*)

2.2. Methods

2.2.1. Food Consumption Survey

This is a descriptive study which took place over 3 weeks in six (6) municipalities in the Abidjan district (Côte d'Ivoire), namely Yopougon, Abobo, Adjamé, Koumassi, Port-Bouet and Cocody. Any person (man and woman), aged 18 and over, from any professional field, who could clearly indicate their eating habits were interviewed using a questionnaire. In total, 320 people were interviewed in all of these municipalities.

2.2.2. Glycemic Responses of Foods

2.2.2.1. Study Type and Population

This is an experimental study, which involved twenty (20) subjects (10 men and 10 women) volunteers aged between 18 and 30 years old. These people were apparently healthy (neither pre-diabetic, nor diabetic, nor hypertensive, nor obese) and gave informed oral consent.

2.2.2.2. Preparation of Dishes Consumed

These dishes were prepared according to the culinary habits previously described by the populations surveyed. The rice was cooked in water for around thirty minutes. The different ingredients of the raw vegetables (onion, tomato, cucumber, lettuce, etc.) were washed, cut and then oil and seasoning were added. Leafy vegetables were consumed in the form of sauces (spinach leaf sauce and potato leaf sauce). These leaves and other ingredients (onion, tomato, pepper, etc.) were cleaned, washed, cooked in water then seasoned with oil and spices at the end of cooking.

2.2.2.3. Biochemical Characterization of Consumed Foods

The protein [6], lipid [7], ash and fiber [6] and total carbohydrate [8] contents were determined by standard methods.

2.2.2.4. Course of the Study

The study took place over 7 days. Before the start of the sessions, each subject was fasted for 10 to 12 hours. On the 1st day, subjects consumed cooked white rice (55 g). On the 2nd day, cooked white rice (55 g) preceded by lettuce salad (50 g) taken as a starter, was consumed. On the 3rd day, cooked white rice (55 g) preceded by raw vegetable salad (50 g) taken as a starter was consumed. On the 4th day, cooked white rice (55 g) followed by an orange (150 g) taken as dessert were consumed. On the 5th day, cooked white rice (55 g) followed by a sweet banana (150 g) taken as dessert were consumed. On the 6th day, cooked white rice (55 g) was consumed with potato leaf sauce (150 g). On the 7th day, cooked white rice (55 g) was consumed with spinach leaf sauce (150 g).

After consumption of these different combinations, the subjects' blood sugar levels were recorded over a period of 2 hours at T 0 min, T 15 min, T 30 min, T 45 min, T 60 min, T 90 min and T 120 min.

2.2.3. Statistical Analyzes

Statistical analysis of the data was carried out using SPSS 2017 software. All 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's test (comparison of two means) and Duncan's test (comparison of more than two means) at the significance level set at 5%.

3. Results and Discussion

3.1. Results

3.1.1. Characteristics of the Populations Surveyed

Table 1 presents the socio-professional characteristics of the population surveyed. These populations were surveyed in the different communes as follows: 23% in the communes of Abobo and Yopougon, 09% in the commune of Cocody, 16% in the communes of Port-Bouet and Koumassi, 13% in the commune of 'Adjamé. Most of the 320 people surveyed were men (57%), aged between 18 and 50 (57%). Very few of them indicated that they were diabetic (05%), hypertensive (09%) or obese (02%).

Table 1. Characteristics of the people surveyed

Parameters studied			Number	Proportion (%)
Survey sites	Localities	Abobo	110	23,00
		Yopougon	110	23,00
		Cocody	43	09,00
		Port-Bouet	76	16,00
		Koumassi	76	16,00
		Adjamé	65	13,00
		Total	480	100,0
Social characteristics	Gender	Male	273	57,00
		Feminine	207	43,00
	Age range	18 – 30 ans	366	76,41
		+ de 30 ans	114	23,59
	Personal history	Diabetes	24	05,00
		High blood pressure	43	09,00
		Obesity	9	02,00

Table 2. Most consumed raw vegetables, cooked leafy vegetables and fruits

	Food	Number	Consumer population (%)	Quantity consumed (g)	Frequency of consumption (j)
Raw vegetables	Lettuce salad	212	44,27	[150 – 250]	[2j/7 – 5j/7]
	Vegetable salad	183	38,21		
	Avocado with vegetables	84	17,52		
Leafy vegetables	Potato leaves	323	67,34	[150 – 200]	[1j/7 – 2j/7]
	Spinach leaves	110	22,92		
	Taro leaves	47	09,74		
Fruits	Orange	174	36,33	[150 – 200]	[1j/7 – 3j/7]
	Sweet banana	159	33,26		
	Mango	147	30,41		

3.1.2. Most Consumed Foods Rich in Dietary Fiber

Table 2 presents the raw vegetables, cooked leafy vegetables and fruits most consumed by the populations surveyed. Lettuce salad (44.27%), raw vegetable salad (38.21%) and avocado with vegetables (17.52%) were among the raw vegetables widely consumed as a "starter". These foods were consumed between 150 and 250 g per meal 2 to 5 days per week. Potato leaf (67.34%), spinach (22.92%) and taro (09.74%) sauces were the most consumed cooked leafy vegetables. These foods were consumed between 150 and 200 g per meal 1 to 2 days per week. Orange (36.33%), sweet banana (33.26%) and mango (30.41%) were the most consumed fruits. These fruits were consumed between 150 and 200 g per meal for 1 to 3 days per week.

3.1.3. Biochemical Composition of the Foods Studied

Table 3 presents the macronutrient composition of white rice, raw vegetables, cooked leafy vegetables and fruits studied. Rice is very rich in total carbohydrates with 83 g/100g but low in fiber (0.35 g/100g). Excluding onion (06.39 g/100g) and carrot (07.59 g/100g), raw vegetables have low total carbohydrate contents with contents varying between 01.6 g/100g (cucumber) and 02.5 g/100g (lettuce) and high fiber contents with values varying between 01.55 g/100g (cucumber) and 02.7 g/100g (carrot). Orange and sweet banana are rich in total carbohydrates and fiber. The values are respectively 09.5 g/100g and 22 g/100g for total carbohydrates and 2.09 g/100g and 3.1 g/100g for fiber. Potato and spinach leaves are low in carbohydrates and high in fiber. The values are respectively 02.77 g/100g and 1.90 g/100g for total carbohydrates and 3.03 g/100g and 3 g/100g for fiber.

Table 3. Biochemical composition of the foods studied

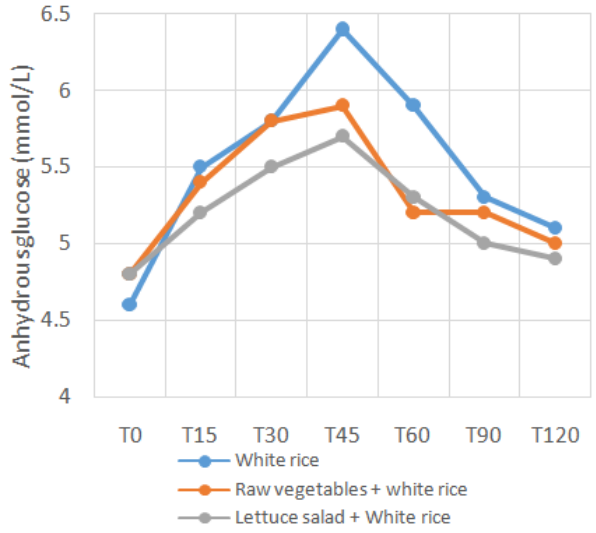
	Biochemical parameters			
	Total carbohydrates (g/100g)	Lipids (g/100g)	Protéins (g/100g)	Fibers (g/100g)
White rice	83±0,13 ^{g}	0.4±0,1 ^{d}	07.5±0,8 ^{e}	0.35±0,08 ^{a}
Lettuce	02.5±0,07 ^{b}	0.3±0,1 ^{d}	01.8±0,03 ^{e}	02.05±0,1 ^{a}
Onion	06.39±1,3 ^{c}	0.5±0,01 ^{e}	1.19±0,07 ^{c}	02.60±0,2 ^{c}
Tomato	01.7±0,15 ^{a}	0.3±0,02 ^{cd}	0.8±0,03 ^{b}	01.60±0,08 ^{b}
Cucumber	01.6±0,7 ^{a}	0.2±0,01 ^{c}	0.6±0,03 ^{a}	01.55±0,4 ^{b}
Carrot	07.59±1,1 ^{d}	0.054±0,01 ^{a}	0.63±0,13 ^{a}	02.7±0,8 ^{c}
Orange	09.05±1,03 ^{e}	00±0,00 ^{e}	01.03±0,03 ^{e}	02.09±0,07 ^{e}
Sweet banana	22±2,1 ^{f}	0.2±0,03 ^{c}	1.2±0,4 ^{c}	03.1±0,18 ^{d}
Potato leaves	02.77±0,22 ^{b}	06.17±01,1 ^{e}	02.55±0,10 ^{e}	03.08±0,15 ^{e}
Spinach leaves	01.9±0,5 ^{a}	0.1±0,01 ^{b}	3±0,2 ^{d}	3±0,11 ^{d}

The average values on the same column indexed by the same letters are not statistically different in the test at $P < 0.05$.

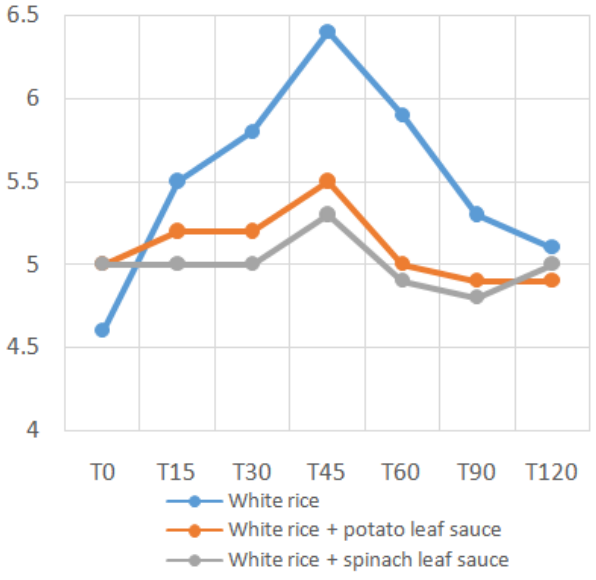
3.1.4. Glycemic Responses after Consumption of White Rice, Raw Vegetables, Cooked Vegetables and Fruits

Figure 1a, Figure 1b and Figure 1c present the glycemic responses of white rice, white rice + raw vegetables, white rice + cooked leafy vegetables and white rice + fruit. After consuming these food combinations, the subjects' postprandial blood sugar levels increased. They increased from 4.6 mmol/L (at T0min) to reach a peak of 6.4

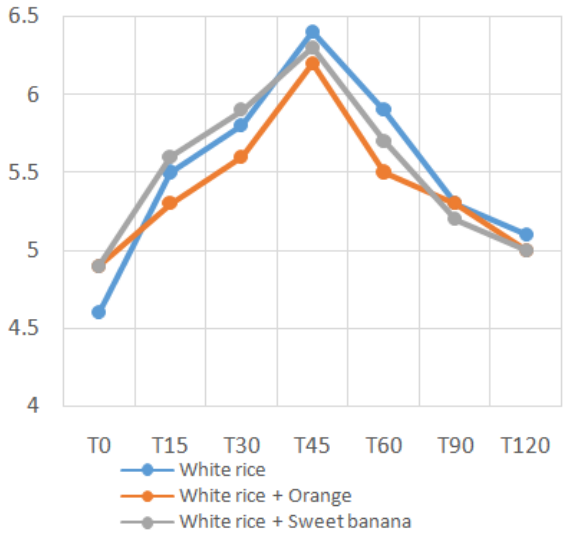
mmol/L; 5.9 mmol/L, 5.7 mmol/L, 5.5 mmol/L, 5.3 mmol/L, 6.2 mmol/L, 6.3 mmol/L at T 45min respectively for white rice, raw vegetables + white rice, lettuce salad + white rice, white rice + potato leaf sauce, white rice + spinach leaf sauce, white rice + orange and white rice + sweet banana. These blood glucose levels subsequently began to gradually decline, reaching values of 5.1 mmol/L at T 120 min; 5 mmol/L, 4.9 mmol/L, 5 mmol/L, 4.9 mmol/L, 5 mmol/L and 5 mmol/L respectively for white rice, raw vegetables + white rice, lettuce salad + white rice, white rice + potato leaf sauce, white rice + spinach leaf sauce, white rice + orange and white rice + sweet banana. The glycemic responses after consumption of white rice + fruit (orange, sweet banana) are the highest, followed by those after consumption of white rice + raw vegetables (raw vegetables, lettuce salad) and white rice + leaves sauces (potato leaves, spinach leaves).



Glycemic responses of white rice, raw vegetable salad + white rice, lettuce salads + white rice.



Glycemic responses of white rice, white rice + potato leaf sauce, white rice + spinach leaf sauce.



Postprandial glycemic responses of white rice, white rice + orange, white rice + sweet banana

Figure 1. Glycemic responses after consumption of white rice, raw vegetables, cooked vegetables and fruits

3.2. Discussion

The results of the food consumption survey revealed that the population surveyed was young (76.41%) and made up mainly of men (57%). Few of them indicated being diabetic (5%), hypertensive (9%) and/or obese (2%). These results agree with those of several studies carried out at the national level by government authorities which show a young Ivorian population with a significant proportion of men and including diabetic, hypertensive and obese people [9,10].

Physicochemical analyzes of foods have shown that rice is very rich in carbohydrates (83g/100g) and very low in fiber (0.35g/100g). They also showed that the foods studied, known to be rich in dietary fiber, namely fruits (sweet banana, orange) are the richest in carbohydrates (respectively 22g/100g and 09.5g/100g) and in fiber (respectively 3 .1g/100g and 02.09g/100g) compared to leafy vegetables (potato leaf, spinach leaf) and raw vegetables (lettuce, onion, tomato, cucumber, carrot) which are low in carbohydrates (between 1.9g/100g and 2.77g/100g) and rich in fiber (between 1.55g/100g and 3.08g/100g). Rice, being a reserve organ, its endosperm is made up of cells containing a significant number of storage organelles, namely starch [11]. This explains its high carbohydrate content.

Also, the glycemic responses after consumption of rice combined with foods rich in dietary fiber (fruits, raw vegetables, leafy vegetables) are lower than those after consumption of rice in isolation. This could be explained by the fact that the fiber contained in these foods helps reduce postprandial hyperglycemia and glucose intolerance [12]. Also, in addition to their effect on glycemic responses, dietary fiber has several other beneficial effects for the health of consumers, notably by helping to avoid constipation, obesity, hypercholesterolemia, etc.

The comparative study of the effect of foods rich in dietary fiber also showed that the glycemic responses after consumption of rice associated with fruits (sweet banana, orange) are higher than those after consumption of rice associated with raw vegetables and leafy vegetables. This could be explained by the higher carbohydrate content of fruits compared to raw vegetables and leafy vegetables. These different types of foods therefore have different impacts on glycemic responses due to their intrinsic characteristics. Indeed, the classification of fruits, raw vegetables and leafy vegetables in the plant kingdom justifies their different biochemical composition. Fruits are known to contain a significant proportion of carbohydrates in the form of fructose [13] and raw vegetables and leafy vegetables to be low in carbohydrates [14]. Consumption of a carbohydrate food combined with one or other of these foods (fruit, raw vegetables or leafy vegetables) leads to different glycemic responses. [15,16] who also showed from their work that postprandial glycemia of foods depends on the intrinsic and extrinsic characteristics of the food consumed, in particular its nature, corroborate our results. This greater increase in blood sugar after ingestion of rice + fruit would be mainly due to the hydrolysis of the fructose contained in this fruit [17], increasing the peak of the glycemic response.

The rise in average or high postprandial blood sugar after ingestion of food is explained by the action of several digestive enzymes including salivary α-amylase, pancreatic amylase, etc., which hydrolyze throughout the gastrointestinal tract, starch into simple sugars which pass directly into the blood through the small intestine, thus causing a significant rise in blood sugar [18]. This rise in blood sugar is all the more significant as the quantity of products of this hydrolysis is high, which explains the different blood sugar peaks observed after consumption of these different foods.

4. Conclusion

This study showed that certainly fruits, raw vegetables and cooked vegetables are rich in dietary fiber but their intrinsic biochemical compositions are different. Fruits contain a lot of carbohydrates, compared to raw vegetables and leafy vegetables. This resulted in higher glycemic responses after consumption of rice + fruit than rice + raw vegetables and rice + leafy vegetables. However, the consumption of rice leads to higher glycemic responses than those of rice + fruit, rice + raw vegetables and rice + leafy vegetables.

For a better balance of blood sugar levels in healthy subjects and diabetics, it is therefore advisable to consume carbohydrate foods accompanied by one of these foods rich in dietary fiber, with a preference for raw vegetables and leafy vegetables.

Competing Interests

The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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