

Comparison of Glycaemic Indices of Four Nigerian Staple Diets in Adult Male Wistar Rats

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Authors' contributions

This work was carried out in collaboration among all authors. This work is a product of group research and every author contributed immensely from time of conceptualization, experimentation, analysis and manuscript writing. All authors read and approved the final manuscript.

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ABSTRACT

The glycaemic indices (GI) of food paste made from wheat, corn, yam, flours and garri in apparently healthy rats using glucose as standard control and water as normal control were determined through Laboratory-experimental design. This was achieved based on the effect of these different selected carbohydrate diets on postprandial glycaemia of the animal model which resulted on variable glucose response. The proximate analysis of the processed diet from wheat, corn and yam showed higher fat and protein contents than that of garri diet. Also, yam diet showed the lowest carbohydrate. The fibre content was shown to be higher in garri with the lowest in yam containing diet. Each of these selected carbohydrate diets contained 56.85% starch. A total of eighteen (18) adult male wistar rats divided into six groups which consisted of three rats each were used in the course of this study. Animals were starved throughout the night for twelve (12) hours and their blood glucose level tested at time zero, before the test food containing 2 grammes of carbohydrate per kilogramme body weight were cautiously administered. After a time interval of 15, 30, 45, 60, 90 and 120 minutes, the blood glucose was determined. α -amylase digestibility of the yam, corn, and wheat diets were higher than that of garri diet. The glycaemic index of yam diet (73.8%) was the highest, followed by that of corn diet (70.4%), wheat diet (70.2%) and garri (61.5%). The glycaemic indices of all the rat diets were less than that of the glucose standard (100%). Comparatively, the glycaemic indices of yam, wheat and corn diets did not differ significantly ($p>0.05$), while that of garri was significantly ($p<0.05$) lower.

Keywords: Glycaemic index; wheat; corn; garri; yam.

1. INTRODUCTION

The constituents of the various form of carbohydrates (e.g., starch, lactose, sucrose) are metabolized to the monosaccharide, glucose; and this enters the general circulation causing a temporary rise in blood glucose levels [1]. Carbohydrates have been classified as 'simple' or 'complex' based on their effects on health and this may be described based on their physiological effects; which depend on the type of sugars contents (e.g. glucose, fructose, or galactose) and the physical form of the carbohydrates (e.g. particle size and rate of hydration) [2]. The glycaemic index concept, which was proposed by Jenkins et al. is a value that describes the rise in blood glucose following the intake of carbohydrate foods, compared to the two hours (2h)-hyperglycaemia induced by the intake of an equivalent load of a standard carbohydrate food [3]. The glycaemic index of a given food is defined as the incremental area under the blood glucose response curve (IAUC) following the intake of a given amount of carbohydrate portion of the food, expressed as a percent of the IAUC following the intake of the same amount of carbohydrate from the standard (glucose =100 or bread =71) by the same individual [3]. According to Foster-Powell et al. [4] glycaemic index food could be classified as high (>70%), medium (55-69%) and low (<55%). Many food factors may contribute to the

reproducibility of glycaemic index and constant presence of high postprandial glycaemia (above 140 mg/dl two hours after a meal) causes oxidative stress [5], chronic capillaries damage, acute endothelial damage, a rise in protein glycation [6] and rise in blood clotting [7]. These settle for unfavourable processes and various disease condition [8]. Yam, maize, wheat and garri are staple diets in Nigeria and other West African countries where carbohydrate rich foods form bulk of diets for greater number of population with its associated health risks as typified in greater number of people suffering from diabetes. It is therefore imperative that the glycaemic indices of such staple diets are understudied to afford the people the opportunity to adhere to proper dietary management. This work was therefore aimed at determining the glycaemic indices of wheat, corn, yam flours and garri in apparently healthy rats.

2. MATERIALS AND METHODS

2.1 Food Sample and Reagents

The reference food (Allenbury's glucose D), standard rodent pellet, corn, wheat, yam flour and garri, crayfish, bone meal, premix, soya beans, salt and palm kernel were purchased from Ogige market, in Nsukka with GPS coordinate (6° 50' 34.5912" N and 7° 22' 23.7576" E) while rice husk was obtained in

Adani with GPS coordinate(6°44'23.0"N 7°00'40.2"E) both in Enugu State, Southeast Nigeria.

2.2 Preparation of Diets

The method described by Ezeanyika [9] was used for the formulation of the rat diets. The corn and wheat flours were processed from their raw grains by grinding and then the ingredients were weighed based on the amount required as shown in the Table below. The food samples used as the carbohydrate sources were prepared separately by stirring in a bowl containing boiled water until they were satisfactorily and consistently made ready for consumption, they were then mixed with other ingredient in a uniform way, as shown in the Table 1, to avoid the introduction of a possible variable that may affect the study results. They were made into pellet and dried in the oven for three days at 40°C.

2.3 Proximate Analysis of the Food Samples

The methods used for proximate analyses of the prepared selected carbohydrate diets were as described by AOAC [10] and FAO/WHO [1]

2.4 Experimental Animals

A total of eighteen adult male Wistar rats (110 - 124 g body weights) were used for the study. All animals were obtained from the Faculty of Veterinary Medicine, University of Nigeria, Nsukka. They were housed individually in the Animal House of the Department of Pharmaceutical Sciences in a controlled condition, 12 hours light and dark cycle. These animals were split into six groups consisted of three animals each. Distilled water was offered *ad libitum*. Animals were starved throughout the night for twelve (12) hours and their blood glucose level tested at time zero before test food containing 2 gramme of carbohydrate per kilogramme body weight were cautiously administered. After time interval of 15, 30, 45, 60, 90 and 120 minutes, the value of blood glucose was determined. The same method was performed when 2 g standard glucose dissolved in distilled water was administered.

2.5 Measurement of Blood Glucose Response

Blood glucose was measured using accu-chek glucometer after blood samples were taken. Determination of Glycaemic Index (GI) for

various selected carbohydrate diet was achieved by calculating the Incremental Area Under two hours of blood glucose response Curve (IAUC) for each diet and compared with the incremental area under curve for glucose solution standard according to the method of Wolever et al. [11] using the following equation:

$$GI = \frac{\text{incremental Area Under 2hr blood glucose curve for food}}{\text{incremental area under 2hr blood glucose curve for glucose}} \times 100$$

2.6 Data Analysis

Statistical Package for Social Sciences (SPSS) version 16 was adopted for analyzing the biodata obtained. Results were expressed as mean ± standard deviation (S.D). Comparisons between the groups were recorded using Analysis of Variance (ANOVA). Statistical significance was set at p<0.05.

3. RESULTS

3.1 Proximate Compositions of the Test Food Samples

Table 2 below revealed the proximate compositions of the selected carbohydrate diet. Comparatively, result shows that the carbohydrate content of yam was low compared to that of garri, wheat, and corn diet; with corn diet having the highest amount of carbohydrate. Garri diet type had the least fat and protein contents while the others had similar fat contents. The moisture contents of corn and wheat were lower when compared with garri and yam diet types. The %w/w ash and fibre contents were similar across the diet types used in this study.

3.2 Blood Glucose Concentration of the Test Food Samples

The blood glucose concentration attained after the animal model were fed the selected carbohydrate diet and reference diet (glucose) are graphically displayed in Figs. 1–4. It was observed that the blood glucose concentration provoked by selected carbohydrate diet was significantly lower than that of the reference diet. Fig. 5 showed the comparative effect of the selected carbohydrate diet of blood glucose concentration. Comparative analysis of the responses to the diets revealed that yam diet elicited a higher increase in blood glucose

response when compared with other diets. Wheat and corn diets provoked nearly similar blood glucose response and the same peak (126 mg/dl) after 45 minutes. Garri diet elicited the least blood glucose response across the duration of time observed. Also, the Fig showed almost equal concentration of glucose released from corn diet (118 mg/dl), garri diet (124 mg/dl) and wheat diet (123 mg/dl) at time 30 minutes. There were significant ($P<0.05$) difference in blood glucose response of yam diet when compared to the other test diets.

3.3 Glycaemic Index of the Selected Carbohydrate Diets

The Glycaemic Index of the food samples are shown in Fig 6. All the test samples are high glycaemic index foods, except garri diet which is a medium glycaemic index food. The glycaemic index of yam, wheat and corn diets did not differ significantly ($P>0.05$) but garri diet had a significantly lowered ($P<0.05$) glycaemic index when compared to other diets.

Table 1. Composition of diet on dry matter

Ingredients /diets	Garri	Corn flour	Wheat flour	Yam
	56.85	56.85	56.85	56.85
PalmKernel Cake	6.69	6.69	6.69	6.69
Rice Husk + Bran	3.35	3.35	3.35	3.35
Soya Beans	22.49	22.49	22.49	22.49
Crayfish	5.62	5.62	5.62	5.62
Bone Meal	4.00	4.00	4.00	4.00
*Premix	0.50	0.50	0.50	0.50
Salt	0.50	0.50	0.50	0.50

*Premix composed of vitamin A 8,000,000 I.U, vitamin D 8,000 I.U, nicotinic acid 12.0g, calcium pantothenate 7g, vitamin B6 1g, vitamin B₁₂ 8.0g folic acid 0.20g, biotin 0.025g, choline chloride 50.0g, zinc 58.50g, copper 10g, iodine 0.31g, cobalt 0.35g and selenium 0.04g. (Ezeanyika, 1995)

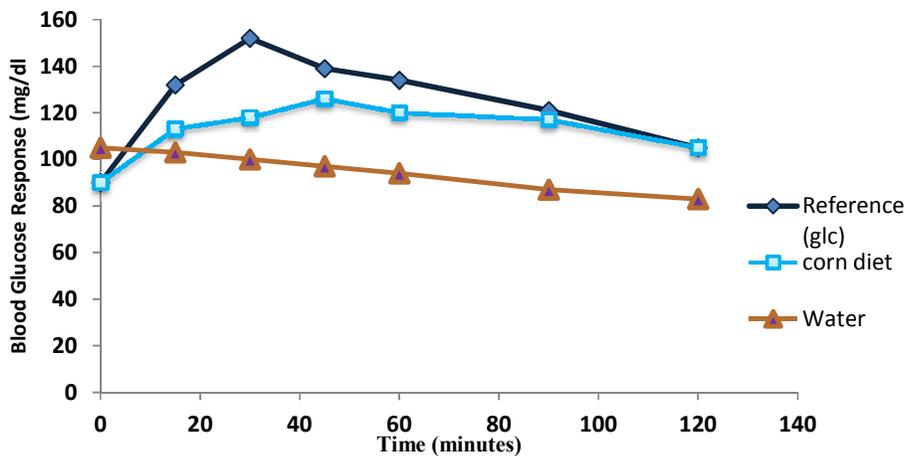


Fig. 1. Average two-hour blood glucose response curves for equal-carbohydrate portions of the reference food (glucose), selected carbohydrate diet (corn diet) consumed by the same group of rats

Table 2. Composition of rat diet in terms of 2g edible portion

Rat diet type	Carbohydrate (%) [*]	Fat (%)	Protein (%)	Moisture (%)	Ash (%)	Fibre (%)
Garri (eba)	50.5 ± .014	1.2 ± .005	16.8±.002	16.95 ± .004	5.7 ± .004	8.8±.003
Corn	53.4 ± .013	2.8 ± .004	20.±.003	8.9 ± .004	6.1 ± .003	8.4±.005
Wheat	50.1 ± .005	2.8 ± .006	25.0 ± .002	5.4 ± .003	8.1 ± .003	8.7±.003
yam	40.3 ± .009.	2.9 ± .002	21.3±.006	22.2 ± .004	5.6±.003	7.8±.003

^{*}by difference; n=3(Mean±SD)

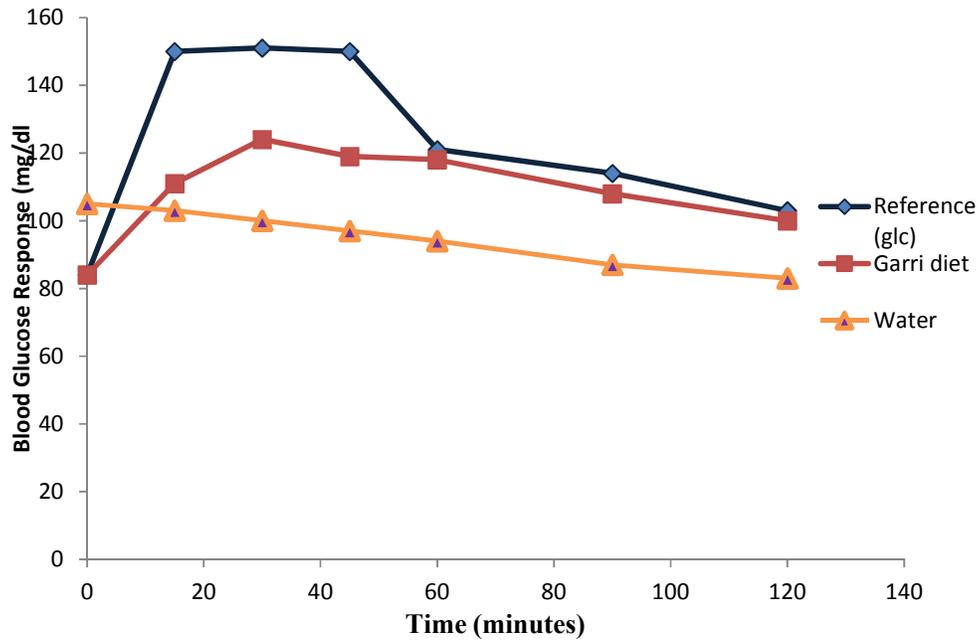


Fig. 2. Average two-hour blood glucose response curves for equal-carbohydrate portions of the reference food (glucose), selected carbohydrate diet (garri diet) consumed by the same group of rats

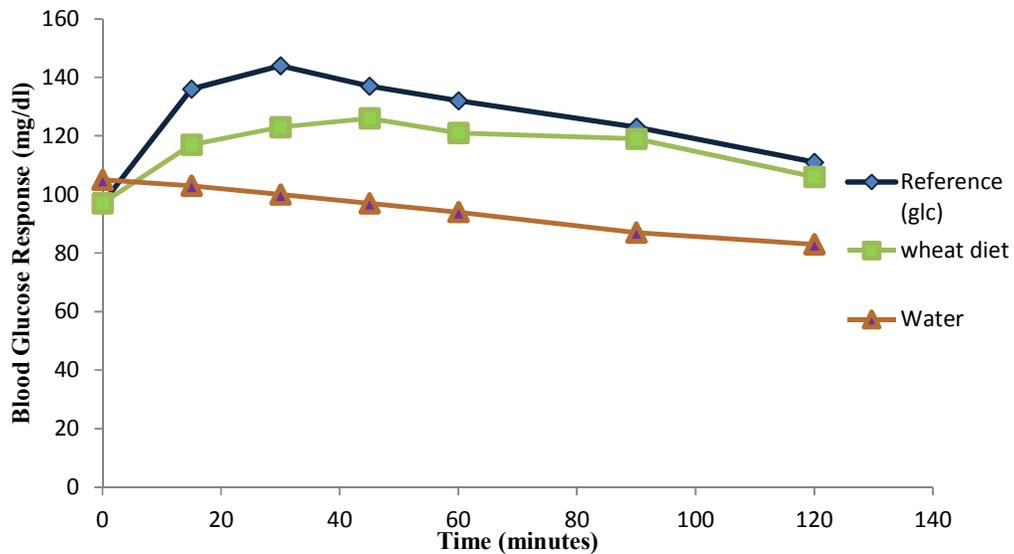


Fig. 3. Average two-hour blood glucose response curves for equal-carbohydrate portions of the reference food (glucose), selected carbohydrate diet (wheat diet) consumed by the same group of rats

4. DISCUSSION

Determination of the relative glycaemic indices of four Nigerian staple foods: Corn, wheat, yam flours and garri was the goal of this study. These

are all carbohydrate-based foods which are made into a paste and eaten with varieties of soup. In attempt to actualize this set goal, these foods were incorporated with other ingredients as shown in Table 1.

Proximate analyses of different experimental diets used in this study showed that the food items have some similarities in terms of nutrient composition, especially in carbohydrate, protein, fat and fibre contents. This could be as a result of ingredients incorporated as shown in Table 1.

The effects of corn, garri, wheat and yam diets on blood glucose response of the test animals relative to reference (glucose) showed that the test (corn, garri, wheat and yam) diets induced lower responses in blood glucose than the reference, indicating a slower release of glucose from the test diets relative to the reference. This could be attributed to the diets composition, especially their content of fibre, fat and protein. Fibre in food is known to delay gastric emptying thus slowing the rate of glucose release into the circulation [11]. Complex carbohydrates have been thought to be beneficial in slowing the glycaemic response, since they have to be converted to their monosaccharide units before being absorbed into the bloodstream [12]. Fat is also known to reduce jejunal motility and postprandial flow rates in the intestine, hence decreasing the glycaemic response, while protein may increase the osmolarity of stomach content, thereby reducing the rate of gastric emptying [13].

The result of the comparative effects of the test diets on blood glucose concentration showed that the blood glucose response to yam had a more significant elevation ($P < 0.05$) than the other test diets. When the peak of the blood glucose level attained is considered as the only factor in glucose response, yam diet is exceptionally a threat, since in the case of diabetics, insulin may not be sufficient to handle this raised level of blood glucose; but when time of highest blood glucose concentration is an added factor, the blood glucose release rate and clearance rate reflects the dangers inherent in this food because of the low rate of release and clearance. This could lead to a build-up of glucose in the bloodstream, resulting to increase in blood glucose concentration. However, there was no significant difference observed between the other test diets. For other foods, when the peak of blood glucose is taken as a single factor, no significant ($p > 0.05$) difference in blood glucose was observed; but with time as an additional factor, wheat and corn diets seem to be the next threatening diets when compared to garri

diet. Garri diet was shown to have the highest clearance rate when compared with the other diets. This could suggest higher glucose uptake with garri diet compared to the other diets, thereby decreasing the concentration of glucose in the blood; hence, preventing hyperglycaemia.

The variability in the blood glucose responses to these diets may be attributed to the nature of the starch (amylose/amylopectin content) present. For example, the amylose content of yam (21%) [14] is lower than that of the other test diets. Garri contains (30%) amylose [15], while both corn and wheat contain 25% amylose [16,17], respectively. High amylose starch has been shown to be digested far more slowly than the high amylopectin starch [18]. This was supported by the work of Kabir et al. [19], which reported that when starches with different amylose-amylopectin ratios are incorporated into a meal, the one with the higher amylopectin starch showed higher glycaemic index than that of the low amylopectin starch for normal and diabetic rats. This was further confirmed by the work of Thannoun and Al-kubati, [20] which showed that a higher ratio of amylose to amylopectin in foods decreases the digestion of the total starch and consequently decreasing the glycaemic index values. The amount of fibre in garri ($8.8 \pm 0.003\%$) was shown to be higher than that of the other test diets. This may have attributed to its lower glycaemic index as compared to the other food samples, since fiber reduces insulin secretion by retarding the rate of nutrient absorption following ingestion of the diet and also may reduce the postprandial hyperglycemia. This is further buttressed by the works of Bell and Sears, [21] and McKeown et al. [22] which showed that foods rich in fiber have a protective effect against hyperglycemia and hyperinsulinaemia because they reduce postprandial blood glucose levels and hence glycaemic index.

The glycaemic indices of food samples are directly correlated with the glycaemic responses of the food. From the study, the glycaemic indices were obtained as follows; glucose 100%, yam 78.3%, corn diet 70.4%, wheat 70.2% and garri 61.5%. According to glycaemic index scale rating [23], corn, wheat and yam are known to be high glycaemic index foods, while garri is known to be a medium glycaemic index food.

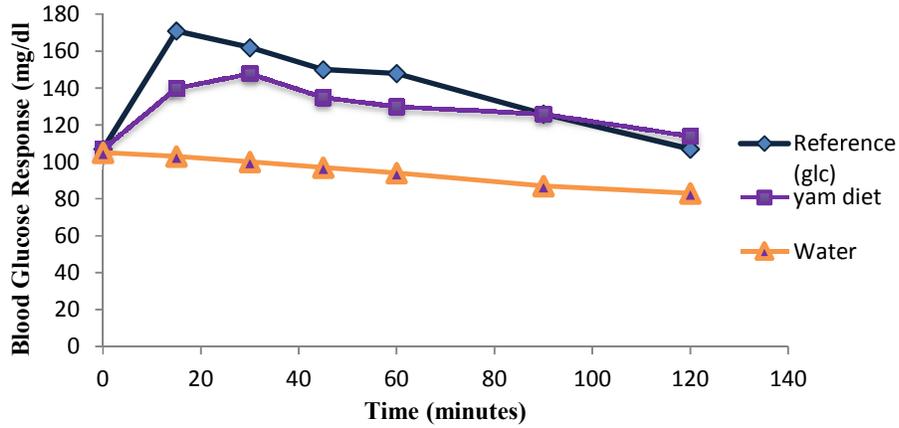


Fig. 4. Average two-hour blood glucose response curves for equal-carbohydrate portions of the reference food (glucose), selected carbohydrate diet (yam diet) consumed by the same group of rats

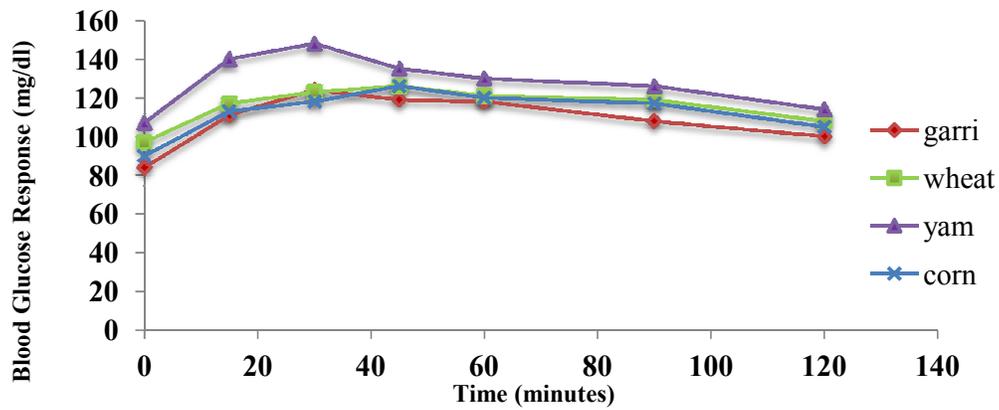


Fig. 5. Average two-hour blood glucose response curves for the carbohydrate diets (yam,wheat, corn and garri diets)

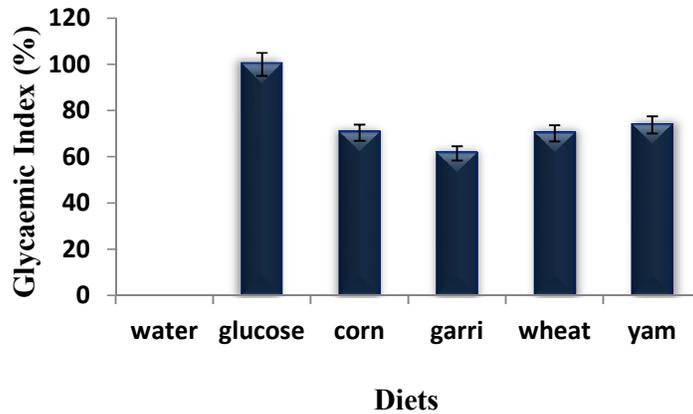


Fig. 6. Graphical representation of the glycaemic indices of the selected carbohydrate diets

5. CONCLUSION

The four selected carbohydrate diets elicited different blood glucose response and clearance rate in the test animals. This variation was also obvious in the glycaemic indices calculated from the response rates. Comparatively, the glycaemic indices of yam, wheat and corn diets did not differ significantly ($p>0.05$), while that of garri was significantly ($p<0.05$) lower. Conclusively, the glycaemic indices of wheat, garri, corn and yam diets were analyzed, as part of developing a glycaemic index database for popular Nigeria carbohydrate diets. Based on the standard classification of the meals for glycaemic index in humans [24], wheat, corn and yam diets would be classified as high glycaemic index foods, while garri diet would be classified as an intermediate glycaemic index food. These observations may serve as a valuable guide to health professionals, including dieticians and nutritionists who often need to recommend diets for different people

ETHICAL APPROVAL

Animal Ethic committee approval has been taken to carry out this study.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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