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DIETARY SALT AND THE GLYCAEMIC RESPONSE TO MEALS OF DIFFERENT FIBRE CONTENT

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In attempting to resolve the existing controversy on the effect of dietary salt intake on glycaemic responses, we investigated post-prandial plasma glucose levels in 10 healthy normal weight non-diabetic Nigerian subjects (aged 23.1 years ± 1.3 (s.e.m.) with body mass index, BMI 19.9 ± 0.6 kg/m^2) consuming equal amounts of carbohydrate from glucose, boiled yam (low fibre content of 0.9 per cent raw tuber weight) and boiled black-eyed peas (high fibre content of 4.8 per cent dry weight) with and without added table salt (4.25 g). The results indicated no significant differences in fasting, peak and 2-h plasma glucose concentrations and total and incremental areas under the 3-h glucose/time curves in the subjects consuming each meal with and without added salt. Added salt had no influence on the glycaemic index of each meal. We conclude that salt has no effect on the glycaemic response to plain glucose or meals with varying fibre content even in a population known to demonstrate defects in salt handling.

There has recently been some controversy on the influence of salt on the glycaemic response in humans. Thorburn, Brand & Truswell (1986) demonstrated that moderate addition of salt increased the plasma glucose and insulin responses to meals of either bread or lentils. They reasoned that dietary salt exerts this effect by accelerating either the digestion or absorption of starch, an observation that had earlier been reported (Clifford, 1936; Flavin & McMurthy, 1983). Other studies (Gans *et al.*, 1987; O'Donnell, Emmett & Heaton, 1988) where test meals containing glucose, macaroni or mixed meals were given to healthy subjects and patients with ileostomies, however, failed to confirm the observations of Thorburn *et al.* (1986).

Studies on hypertension in different racial groups have shown that, while salt consumption patterns are not different in black and white Americans, the blacks tended to be less salt-tolerant and to retain a salt load more than the whites (Luft, Weinberger & Grim, 1979). This defect has also been documented in black Africans (Osotimehin *et al.*, 1988) and may be a true racial difference although it remains essentially unexplained. However, it is believed to contribute to the relatively high prevalence of volume-dependent (low renin status) hypertension in black populations (Luft *et al.*, 1979, 1982; Osotimehin *et al.*, 1988).

This documented difference in salt handling also makes it important not to transcribe directly any observations made on salt and glycaemia in Caucasians to black Africans. It is even more important as the incidence of diabetes appears to be increasing in tropical populations (WHO, 1985). WHO has indicated that more information is still required on the clinical and biochemical characterization of these tropical forms of diabetes. One index of the liability to develop glucose intolerance is the glycaemic index of glucose excursions to different meals containing equal amounts of carbohydrate (Jenkins *et al.*, 1981, 1984).

We therefore investigated the glycaemic responses to three different (75 g) breakfasts of oral glucose, boiled yam (*Dioscorea spp*) and boiled black-eyed peas (*Vigna unguiculata*) with and without added salt in young healthy male non-diabetic Nigerian subjects who had fasted overnight. We aimed to assess whether or not the addition of salt influenced the postprandial plasma glucose responses. Our results should offer further insight into the controversial relationship between dietary salt and glycaemia and indicate whether the fibre content of meals affects that relationship.

Subjects and methods

Subjects

Ten healthy male Nigerian medical students aged 23.1 years ± 1.3 (s.e.m.) with body mass index, BMI, 19.9 ± 0.6 kg/m^2 volunteered for the study. Only two of the subjects had a family history of diabetes, but none was glucose-intolerant as revealed by the pre-recruitment fasting plasma glucose levels of 4.0 ± 0.1 mmol/l. None of the volunteers was on regular drugs or medications known to influence glucose and/or lipid metabolism; all had been taking diets that regularly contained at least 150 g carbohydrate per day. Six studies were conducted in random order at weekly intervals in the metabolic ward on the morning after a 10–12-h overnight fast. All the subjects voluntarily gave informed consent and the studies were approved by the local Ethical Committee.

Study design

The six test meals contained, on different occasions, 75 g glucose and amounts of boiled yam (*Dioscorea spp*, 280 g raw tuber weight) and boiled black-eyed peas (*Vigna unguiculata*, 122 g dry weight) to give equivalent quantities of carbohydrate and with or without the addition of 4.24 g cooking salt to the prepared meal. The amount of salt used is similar to that used in the earlier studies. Glucose was taken in solution dissolved in 250–300 ml water. Each meal was taken over 5 min and followed with 50 ml water.

The raw yam tuber typically contains per 100 g weight: 112 kcal, 71 per cent moisture, 1.5 g protein, 26.5 g total carbohydrate, 0.1 g fat and 0.9 g fibre, while whole dry black-eyed peas typically contain per 100 g dry weight: 342 kcal, 10.8 per cent moisture, 23.1 g protein, 61.4 g carbohydrate, 1.4 g fat and 4.8 g fibre. The relative fibre content of yam (0.9 per cent) is thus only about 20 per cent that of black-eyed peas. These nutrient compositions were obtained from standard food tables (USDHEW/FAO, 1968). Yam and black-eyed peas are usually consumed by Nigerians with a pepper sauce (although not with any sauce in this study).

Methods

Blood samples were drawn from an indwelling antecubital venous cannula kept patent by regular flushing with small amounts of isotonic saline. The samples were taken fasting (at −15 and 0 min) and then at 15, 30, 60, 90, 120 and 180 min after beginning to consume the meal. Plasma was stored frozen at −20 °C until analysis for glucose (within 1 month of sample collection) by a glucose oxidase method (Trinder, 1969).

Statistics

The results are expressed as means (s.e.m.) and ranges. The total and incremental areas (from fasting) under the 3-h plasma glucose curves were calculated by the trapezoidal rule. The glycaemic index was calculated as the ratio of the incremental area for the meal to that for plain glucose (Jenkins *et al.*, 1981). Statistical comparisons within subjects at the different time points, peak values, glycaemic indices and the different areas and meals were made by paired Student's *t*-tests. The level of statistical significance was $P < 0.05$.

Results

There were no significant differences in glycaemic responses with and without the addition of salt to glucose, yam and black-eyed peas meals at any time point of blood sampling. The peak values for each meal with and without salt were also similar (Table 1). Additionally, there were no significant differences in the total or incremental areas under the 3-h plasma glucose/time curves and in the glycaemic indices for any of the meals with and without salt (Table 2). Although the meals taken without salt appeared to show higher post-prandial plasma glucose levels (Table 1), the differences did not reach statistical significance.

Similar to the report of Gans *et al.* (1987), we did not consider it necessary to assay plasma insulin since our findings on post-prandial glycaemia were essentially negative.

Discussion

In this acute feeding study, it has been shown that addition of moderate amounts of salt to test meals of Nigerian staples with high fibre (black-eyed peas) and low fibre (yam) content had no significant

Table 1. *Fasting, peak and 120-min plasma glucose concentrations (mmol/l) after test meals in the ten subjects (means ± s.e.m. with range).*

Test meals	*Fasting plasma glucose*	*Peak plasma glucose*	*2-h plasma glucose*
Glucose	4.0 ± 0.1 (3.2–4.4)	6.7 ± 0.2 (5.7–7.9)	5.9 ± 0.3 (4.3–6.8)
Glucose + salt	4.1 ± 0.1 (3.7–4.5)	6.8 ± 0.7 (4.4–10.4)	5.5 ± 0.4 (3.6–7.2)
Yam	4.2 ± 0.1 (3.7–4.6)	6.8 ± 0.4 (5.7–9.3)	5.3 ± 0.2 (4.5–6.7)
Yam + salt	4.1 ± 0.2 (3.4–4.9)	6.6 ± 0.2 (5.8–7.8)	5.0 ± 0.2 (4.1–5.9)
Beans	4.1 ± 0.1 (3.5–4.6)	5.5 ± 0.1 (5.1–5.9)	5.0 ± 0.1 (4.4–5.7)
Beans + salt	4.2 ± 0.1 (3.6–4.8)	5.4 ± 0.2 (4.6–6.3)	4.9 ± 0.1 (4.3–5.6)

Table 2. *Total and incremental area under the 3-h curve and the glycaemic indices for the test meals with and without salt (means ± s.e.m. with ranges).*

Test meal	*Area under plasma glucose curve (mmol.h/l)*	*Incremental area (mmol.h/l)*	*Glycaemic index*
Glucose	16.9 ± 0.7 (13.9–22.3)	5.0 ± 0.8 (0.7–10.9)	1.0 ± 0 (1–1)
Glucose + salt	16.5 ± 1.1 (12.0–21.2)	4.3 ± 1.1 (−1.0–9.8)	0.90 ± 0.2 (−0.2–1.5)
Yam	16.2 ± 0.4 (13.4–17.7)	3.7 ± 0.5 (1.7–6.5)	1.0 ± 0.3 (0.3–3.1)
Yam + salt	14.9 ± 0.4 (7.0–17.2)	3.7 ± 0.5 (1.1–6.7)	1.2 ± 0.5 (0.2–5.6)
Beans	14.7 ± 0.4 (13.2–17.0)	2.6 ± 0.5 (−0.3–5.3)	0.7 ± 0.3 (−0.08–2.9)
Beans + salt	14.4 ± 0.3 (12.8–16.3)	1.9 ± 0.3 (0.2–3.4)	0.5 ± 0.1 (0.0–0.9)

effect on the post-prandial glycaemic responses. This is at variance with the report of Thorburn *et al.* (1986) but accords with the observations of Gans *et al.* (1987) and O'Donnell *et al.* (1988). Our study was, however, different from these previous reports being probably the first such report in black subjects known to show impaired salt handling and excretion (Luft *et al.*, 1979; Osotimehin *et al.*, 1988). Furthermore, the specific effect of salt on meals containing different amounts of dietary fibre was assessed. This was considered necessary as fibre supplementation is now routinely recommended in the treatment of diabetes, and any complete assessment of the role of salt in the genesis and treatment of diabetes should investigate any inter-relationships with fibre intake.

In oral rehydration solutions, widely advocated for the management of diarrhoeal disorders in developing countries, a small amount of glucose is added to dietary salt because glucose is believed to facilitate sodium and chloride absorption from the ileum and colon (Flavin & McMurthy, 1983). Whether the converse is also true, ie, salt facilitating intestinal glucose absorption, remains controversial (Gray, 1975). Our results would however suggest otherwise, as the effects of salt on post-prandial glycaemia after plain glucose or complex carbohydrate meals did not differ from effects observed with or without added salt. The results were also unaffected by the fibre content of the meal, since black-eyed peas contain about five times the crude fibre content of yam per unit weight.

All too often, meals for diabetic subjects are changed because of 'novel' reports on post-prandial glycaemia after specific meals. It is therefore important to indicate that our results do not suggest any need to alter the salt content of diabetic diets. The results should not be invalidated on the premise that only non-diabetic subjects were studied, since the previous reports (Thorburn *et al.*, 1986; Gans *et al.*, 1987; O'Donnell *et al.*, 1988), like ours, were on non-diabetic subjects. Moreover, we have no indication that the observations here will be different in diabetic subjects. However, chronic feeding studies with supervised increased salt intake in diabetic and non-diabetic subjects still need to be performed before any really rational conclusions on the relationship of salt with glycaemia can be reached.

In conclusion, we report that acute dietary salt intake had no effect on the glycaemic responses to meals of different fibre content in non-diabetic Nigerians.

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