Glycaemic response of mixed meals with various portions of Green Mustard leaves (*Sawi*) and their effects on perceived appetite and satiety

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ABSTRACT Vegetables, a key source of dietary fibre in the diet, can influence the glycaemic response of a meal, reduce appetite and increase satiety. We investigated the effects of mixed meals with various portions of vegetables (white rice, chicken breast and green mustard leaves (40 g, 80 g,120 g)) on postprandial blood glucose and perceived appetite and satiety. Glycaemic response of three test meals was measured using established methods (n=11). The test meals were not significantly different (repeated measures ANOVA; p>0.05) in glycaemic response (iAUC) but differed in their Visual Analogue Scale (VAS) ratings for perceived appetite and satiety (Friedman's test; p<0.05). The findings suggest that meals containing larger portions of vegetables may not substantially reduce postprandial blood glucose levels but may reduce perceived appetite and increase satiety. Further research is required to confirm these findings.

KEYWORDS: Glycaemic response; Dietary fibre; Vegetables; Blood glucose; Appetite

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INTRODUCTION

Vegetables, low in available carbohydrates, are key sources of dietary fibre in the diet. As such, vegetables tend to have low glycaemic index (GI) and glycaemic response (GR). Glycaemic response is a physiological effect also known as postprandial glycaemia (Agustin *et al.*, 2015) which is the change in blood glucose after any amount of carbohydrate containing food or beverage is consumed. It is well established that most green leafy vegetables have low GI (Atkinson *et al.*, 2021) but there is a scarcity of studies that compare both GR and perceived appetite on the same study participants, serving as their own controls, for relatively isocaloric carbohydrate-rich mixed-meals differing in the portion size of vegetables. It is of public health interest to investigate this because high fibre intake is associated with lower dietary GI (Hardy *et al.*, 2020) and previous meta-analysis on consumption of low GI foods such as fruits and vegetables have been found to decrease risk of non-communicable diseases such as type 2 diabetes (Halvorsen *et al.*, 2021).

For relatively isocaloric carbohydrate-rich mixed meals like white rice, chicken and vegetables that only differ in the portion size of vegetables, the meal with the larger portions of vegetables is expected to be lower in GR. This is because the meal with the larger portion of vegetables contains more dietary fibre. Dietary fibre is known to delay gastric emptying, slowing down the absorption of glucose in the small intestines, which reduce glycaemic response (Qi *et al.*, 2018). Appetite is the desire to eat foods and includes perceived hunger while satiety is the feeling of being full (Leidy & Campbell, 2011). Appetite and satiety may be influenced by consumption of vegetables due to their high dietary fibre content. The information gained from this research could potentially be useful in meal-planning for glycaemic control and body weight management. Hence, we aimed to investigate the effect of carbohydrate-rich mixed-meals with various portions (40 g, 80 g and 120 g) of cooked vegetables (green mustard leaves (*sawi*)) on postprandial blood glucose as well as perceived appetite and satiety.

METHODOLOGY

Study Design and Location

This was an experimental study that used a cross-over, controlled and randomised design on human subjects. Each participant tested a total of three test meals in random order with a washout period of at least three days in between each test meal trial. The study protocol was approved by the Medical Ethics Committee of the Faculty of Medicine and Health Science, Universiti Malaysia Sabah (Approval code: JKEtika UMS 2/22 (9)). Willing participants were given a subject information sheet, briefed about the study protocol and provided informed consent. Glycaemic response trials were conducted at the Nutrition Laboratory, Faculty of Food Science and Nutrition, Kota Kinabalu Campus, Universiti Malaysia Sabah.

Test Meals

Ingredients

Each test meal consisted of 100 g of cooked white rice, 58 g of cooked chicken breast and either 40 g, 80 g, or 120 g of cooked green mustard leaves (*sawi*). This food combination is common in Malaysia. The portion size of vegetables in the test meals were set based on the Malaysian Dietary Guidelines 2020 (NCCFN, 2021), 1 serving of cooked vegetables is approximately 40 g. It was also set based on the findings of a pilot study (n=30) that was conducted before the start of this current research. In the pilot study, green mustard leaves (*sawi*) were found to be the most frequently consumed vegetable and 40 to 120 g of vegetables was usually eaten in a meal. All test meals used the same ingredients (white rice, chicken breast, salt, black pepper, palm oil, chopped garlic, white vinegar, soy sauce, oyster sauce, honey, green mustard leaves (*sawi*)), the same brand of ingredients and were purchased from the same local supplier. All test meals were prepared using the same standard process and recipe as described in the following section. The nutrient composition of the test meals is shown in Table 1.

Table 1. Nutrient composition of test meals

Test meals	Total energy (kJ)	Total CHO (g)	Total protein (g)	Total fat (g)	Total dietary fibre (g)	*Total available CHO (g)
X	449.26	57.25	23.41	14.45	0.93	56.32
Y	459.66	59.05	24.43	14.64	1.73	57.32
Z	470.06	60.85	25.45	14.83	2.53	58.32

Note: X: white rice (100 g), chicken breast (58 g), green mustard leaves (*sawi*) (40 g); Y: white rice (100 g), chicken breast (58 g) green mustard leaves (*sawi*) (80 g); Z: white rice (100 g), chicken breast (58 g) and green mustard leaves (*sawi*) (120 g);
*Available CHO = CHO content – dietary fibre; CHO, Carbohydrate

Preparation

To cook white rice, filtered water (1 cup of rice to 1.5 cups of water) was added to the rice in a rice cooker (Panasonic 1.8L Conventional Rice Cooker, Panasonic Malaysia). For chicken breasts, each side of the chicken breast (raw weight: 70 g) was seasoned with salt (0.5 g), black pepper (0.5 g), chopped garlic (5.15 g) and then left in the refrigerator (4 °C) overnight before the day of the trial. Chicken breast was pan fried with palm oil (4.25 g) for 3 min at medium heat on one side until it turned a golden colour. Then, white vinegar (6.15 g), soy sauce (10.05 g), oyster sauce (4.98 g) and honey (15.38 g) were added to the pan and brought to a simmer for 1 min until the sauce slightly thickened. The chicken breasts were then flipped over to the other side and left to cook for another 6 min. The leaves of green mustard (*sawi*) were taken while stems were removed. Green mustard leaves were stir-fried with palm oil (1 g) and chopped garlic (1 g) for 2.5 min and seasoned with salt.

Glycaemic Response

Glycaemic response trial protocol

Postprandial glycaemic response of test meals was determined according to the protocol by (Brouns *et al.,* 2005). Eleven healthy female volunteers aged 21-23 years, with normal body mass index, that were not-pregnant, not-lactating and were studying at Universiti Malaysia Sabah participated in this study. Height and weight were measured using standard protocol (Lee & Nieman, 2013) and equipment (calibrated stadiometer (SECA, Germany)). Each participant visited the laboratory three times to test a total of three test meals on separate days at intervals of three to five days (over a period of three weeks). During a glycaemic response measurement trial for each test meal, participants were served the test meal along with 200 mL of purified water. Participants were given instructions to finish the test meal within 15 min.

Blood glucose measurement

Participants' blood glucose concentration was measured at set time intervals over two hours after the first bite of the test meal. Finger-prick capillary blood samples were taken using single-use lancets (Accu-Chek Safe-T-Pro Plus, Germany) before the meal (0 minute) and at 15, 30, 45, 60, 90 and 120 min after the first bite of food. A glucometer was used to measure blood glucose (Freestyle Freedom Lite Blood Glucose Monitoring System, Abott DiabetesCare Ltd., CA, USA). Glycaemic response was calculated using the trapezoidal method and expressed as the incremental area under the curve (iAUC) as recommended by the Food & Agriculture Organization (1998) (Brouns *et al.,* 2005).

Perceived Appetite and Satiety Measurements

Participants rated their perceived hunger and satiety levels before the meal (0 minute) and at 15, 30, 45, 60, 90 and 120 min after the first bite of food using the Visual Analogue Scale (VAS) based on Flint *et al.* (2000) as described by Hobden *et al.* (2017). The VAS comprises five questions (questions on satiety, hunger, desire to eat, fullness and prospective consumption), each accompanied by a 100 mm straight line to measure the participants' subjective appetite and feelings.

Data Analysis

Data were entered into Microsoft Excel spreadsheet (Microsoft Corporation) and processed into graphs. Statistical analysis of data was done using Statistical Package for Social Science (SPSS) Version 29.0 (International Business Machine (IBM) Corporation, 2023). The statistical tests used in this study were descriptive and inferential analysis. The mean iAUC of test meals was compared using ANOVA. The median ratings for VAS data were compared using Friedman's Analysis, mean ratings were presented in graphs. For all parameters evaluated in this study, statistical significance of p-value less than or equal to 0.05 (≤0.05) was set.

RESULTS AND DISCUSSION

Study participants' characteristics are shown in Table 2. All study participants fulfilled the inclusion criteria for glycaemic response trial.

Table 2. Characteristics of study participants.

Characteristics (n=11)	Mean ± SD
Age (years)	22.00 ± 0.63
Weight (kg)	53.95 ± 5.90
Height (cm)	159.92 ± 3.23
Body mass index (kg/m^2)	21.07 ± 1.66
Fasting blood glucose (mmol/L)	4.96 ±0.37

There was no significant difference in glycaemic response (iAUC) of the test meals (repeated measures ANOVA; $p>0.05$) (Figure 1). This is contrary to what was expected. It was expected that the meal with the larger portion of vegetables (80 g and 120 g), containing higher amounts of dietary fibre, would have lower glycaemic response compared to the meal with smaller portions of vegetables (40 g). This is because dietary fibre is known to delay gastric emptying, slowing down the absorption of glucose in the small intestines, which reduce glycaemic response (Qi *et al.*, 2018). This, however, was not observed in the current study. This might be explained by the potential dose-response effect of dietary fibre on glycemia in which higher quantities of dietary fibre and therefore, vegetables, may be required to elicit bigger reduction in glycaemic response. Past studies have shown different effects, including dose dependent effects, of soluble (Giuntini *et al.*, 2022) and insoluble (Kabisch *et al.*, 2021) dietary fibres on glycaemic response. Indeed, in this current study, the difference in the amount of dietary fibre contributed mostly by vegetables, between the test meals, is relatively small (Table 1). This means that eating the recommended one to three servings of vegetables (NCCFN, 2021) with a carbohydrate rich mixed-meal, like chicken and rice, at one sitting would elicit similar changes in postprandial blood glucose.

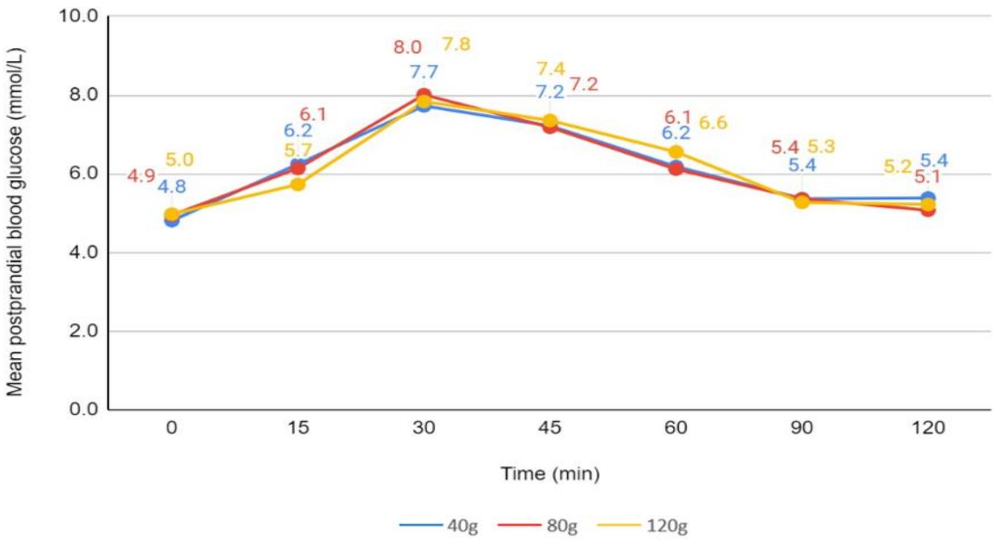

Figure 1. Mean postprandial blood glucose of study participants (n=11) at certain time intervals after consumption of test meals containing 40g, 80g and 120g of green mustard leaves (*sawi*).

In terms of perceived satiety ratings, participants' satiety VAS ratings (Figure 2.A) were significantly higher (comparison of median values using Friedman's test; p-value <0.032 at 15 min; p-value= 0.006 at 30 min and 120 min; p-value = 0.008 at 60 min) for test meals that contained larger portions of vegetables. This was also the case for fullness ratings (Figure 2.B) (Friedman's test; p-value <0.005 at 15 min; p-value= 0.002 at 30 min; p-value = 0.004 at 60 min and p-value= 0.007 at 120 min). The perceived satiating effect of the meal with larger portions of vegetables is probably due to its higher dietary fibre content compared to the test meal with smaller portions of vegetables (Table 1).

It is known that consuming dietary fibre increases gastric distension and this activates certain parts of the brain that are involved in the perception of satiety (Janssen *et al.*, 2011). Another potential mechanism by which dietary fibre could increase satiety is by delaying gastric emptying which enhances the production of satiety hormones (Chambers *et al.*, 2015).

Corresponding to these results, participants' perceived appetite or desire to eat was also significantly lower (Friedman's test; p-value <0.015 at 30 min) for test meals containing larger portions of vegetables (Figure 2.C). A trend of lower perceived hunger ratings was also observed for test meals with larger portions of vegetables (Figure 2.D) but the difference in perceived hunger ratings between the test meals did not reach statistical significance (Friedman's test; p>0.05). These results on perceived hunger, add to the existing inconsistencies in the findings of previous studies regarding the effect of dietary fibre on perceived hunger. Some studies showed significant effect of the dose of dietary fibre on hunger while others did not (Akhlaghi *et al.*, 2022). There are known limitations inherent to the VAS scales used for ratings of appetite and satiety due to their subjective nature. Therefore, this needs to be taken into consideration when interpreting VAS results and future studies should include objective measures such as biomarkers of appetite.

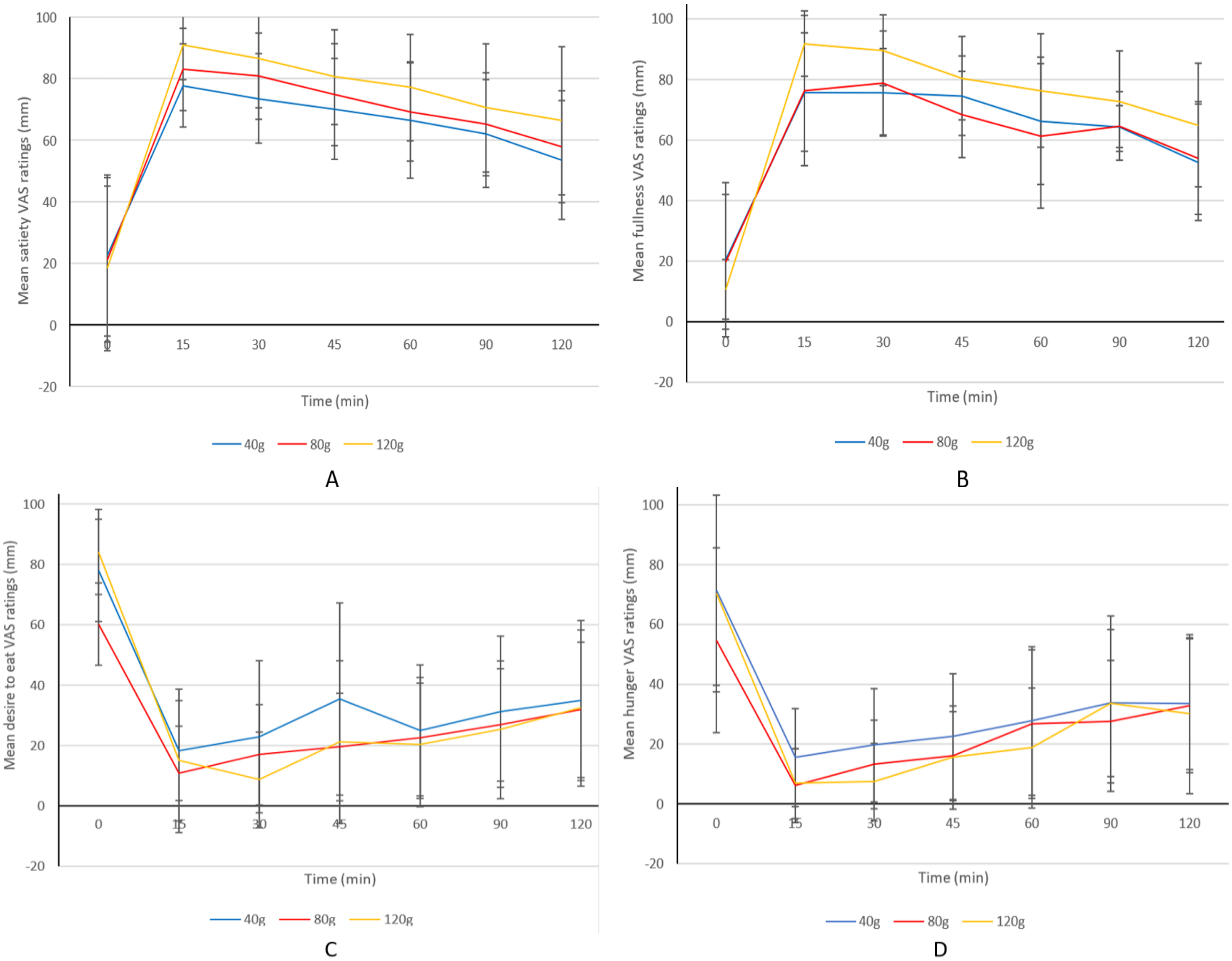

Figure 2. Mean visual analogue scale ratings (VAS; mm) of study participants (n=11) for A, satiety; B, fullness; C, appetite/desire to eat; D, hunger. Values are means, with their standard deviations represented by vertical bars.

CONCLUSION

This paper suggest that carbohydrate-rich meals containing one to three servings (40 g to 120 g) of vegetables may not differ substantially in their impact on postprandial blood glucose levels but larger servings of vegetables in a meal, however, may increase satiety, increase fullness and reduce appetite. Hence, consideration of this in meal planning may be a viable strategy for body weight management but further research is required to confirm these findings.

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