

Energy Density and Satiety of Meals Based on the Healthy Food Plate Model for Filipino Adults

Maria Julia Goloso-Gubat, Edward Vincent J. Magtibay, Jacus S. Nacis,
Robby Carlo A. Tan, Merlyn G. Tajan and Ermelita N. Bautista

Food and Nutrition Research Institute-Department of Science and Technology (FNRI-DOST)

ABSTRACT

Objective. This study aimed to determine the energy density and satiety of meals based on the healthy food plate model for Filipino adults.

Methods. Thirteen healthy adult volunteers consumed breakfast test meals consisting of 1 cup go food, ½ cup grow food and 1 ½ cups glow food, following the recommended proportions in the plate model. Energy density (kcal/g) of the test meals was calculated. Feelings of hunger and fullness were assessed with 100-mm visual analogue scales (VAS) at pre-prandial (0 minute) and at 30, 60, 90, 120, 150, 180, and 240 minutes postprandial. Ghrelin levels at 0, 30, 60, 120, 180, and 240 minutes were determined by radioimmunoassay (RIA).

Results. The test meals had an average energy density of 0.83 kcal/g. Hunger and fullness scores gradually changed with time but hunger remained significantly lower and fullness significantly higher than the pre-prandial levels at 180 minutes postprandial. Ghrelin declined after intake of the test meals and stayed significantly lower than the pre-prandial level at 240 minutes postprandial (30.21 ± 4.58 pmol/L).

Conclusion. Meals following the recommendations in the healthy food plate model for Filipino adults have low energy density and its consumption sustained short-term satiety.

Key Words: energy density, food plate model, fullness, ghrelin, hunger, Pinggang Pinoy, satiety

INTRODUCTION

The *Pinggang Pinoy* (literally translated as “Filipino plate”) is a food-based guide for Filipino adults which promotes the consumption of healthy and balanced meals. It uses a familiar plate icon to provide visual cues and encourage the population to make conscious food decision at meal times. The plate model emphasizes the consumption of locally available foods from the 3 basic food groups during a main meal, represented by rice (go food), fish (grow food), and vegetables and fruits (glow food).

The nutritional goal of the Filipino plate model is calculated based on population-weighted Estimated Average Requirement (EAR) of 2000 kcal/day for energy among Filipino adults aged 19 to 29 years. Following the Acceptable Macronutrient Distribution Range (AMDR), the healthy food plate model recommends that the plate consists of 1 cup whole grains, ½ cup fish or lean meat, ¾ cup vegetables and ¾ cup fruits, estimated at 500–600 kcal on a per-meal basis. While this food combinations and portions are reasonably regarded as healthy, its nutritional quality needs to be defined in terms of energy density and its potential implication in the modulation of appetite.

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Corresponding author: Maria Julia Goloso-Gubat
Food and Nutrition Research Institute –
Department of Science and Technology
DOST Complex, General Santos Ave.,
Bicutan, Taguig City, 1631 Philippines
Telephone: +632 8372071 local 2299
Email: juliagubat@gmail.com

Energy density is defined as the amount of energy in a given weight of food or meal which can serve as a simple proxy indicator of diet quality.^{1,2} It is calculated by dividing the total energy content of a food or meal (kcal or kJ) by its weight (g).^{3,4} The energy density of food (or a meal) is largely determined by its water content because water adds weight but it does not add calories to food thereby reducing the energy density.⁵ Foods with the lowest energy density are those that contain high amounts of water.⁵ Incorporating water-rich foods like vegetables and fruits in the diet tend to lower its energy density and they also have better nutritional quality.¹ Consumption of low energy density diets demonstrated a macronutrient and energy intake closest to the population goals and higher intakes of micronutrients.^{4,6} Low energy density diets have also been reported to be associated with higher satiety.² Satiety is a state of decreased hunger which starts after a meal has ended and persists until feelings of hunger return, and the next meal is initiated.^{7,8} It can be assessed by subjective ratings for appetite parameters, such as hunger and fullness using visual analogue scales (VAS).^{2,7} Laboratory-based experiments have shown that consumption of low energy density foods controls hunger and promotes greater satiety as compared with foods with high energy density.^{9,10} The physiologic effect of a certain food on satiety can be determined by assessing the postprandial changes in the gut hormone ghrelin. Physiologically, ghrelin rise before consumption of a meal (pre-prandial) and fall after eating (postprandial).¹¹ The temporal profiles of ghrelin overlap and are closely associated with hunger scores.^{12,13} This apparent association between ghrelin and short-term appetite control suggests that ghrelin is a valid biomarker for satiety.^{13,14} In the present study, the authors aimed to assess the energy density of meals following the healthy food plate model for Filipino adults. The study also aimed to determine the postprandial changes in hunger and fullness scores, and ghrelin concentration after consumption of these meals.

MATERIALS AND METHODS

Study participants

Study participants (n=13) were 20-55 years old males and females, all of whom were non-smokers, had BMI within the normal range (18.5-24.9 kg/m²), not following weight gain or weight loss regimen, not taking anti-satiety and/or anti-obesity drug, and had no self-declared allergies and/or restrictions to the food items used in the study. Participants had normal fasting blood glucose (FBG) and lipid (triglyceride, high density lipoprotein or HDL, low density lipoprotein or LDL and total cholesterol) levels, based on the World Health Organization (WHO) cutoff and the National Cholesterol Education Program (NCEP) Guidelines, respectively. The protocol was discussed with those who voluntarily signified their interest to participate in the study. Each study participant gave written informed consent, and the study protocol was approved by the FNRI

Institutional Ethics Review Committee (FIERC). The characteristics of the study participants are shown in Table 1.

Table 1. Characteristics of study participants (n=13)

Age (years)	26.62 ± 4.92
Weight (kg)	54.68 ± 5.51
Height (cm)	159.11 ± 5.97
BMI (kg/m ²)	21.56 ± 1.11
FBG (mg/dL)	89.13 ± 5.75
Triglycerides (mg/dL)	68.62 ± 25.27
HDL (mg/dL)	60.29 ± 14.42
LDL (mg/dL)	85.86 ± 19.61
Total cholesterol (mg/dL)	159.93 ± 21.54

Study protocol

Test sessions were held for 5 consecutive days at the Food and Nutrition Research Institute (FNRI) Basal Metabolic Rate (BMR) Laboratory. Study participants were advised to maintain similar routine physical activity, have a restful sleep every night and refrain from alcohol consumption during their participation in the study. They were requested to be on overnight fast (at least 10 hours but not more than 15 hours) and were provided with the test meals upon arrival at the laboratory. They were then asked to rate feelings of hunger and fullness using VAS, at standard time intervals and refrain from eating or drinking until the 4th hour after full consumption of the test meals (i.e., 240 minutes postprandial). Days 1-4 were allocated for the subjects' acclimatization period to the test meals and the study protocol. On day 5, blood samples were drawn from each participant for ghrelin assay.

Test meals

Composition of the breakfast test meals were standardized by a registered nutritionist-dietitian (RND). Following the AMDR, test meals were formulated to contain ≈60% of energy from carbohydrates, ≈15% of energy from protein, and ≈25% of energy from fat. Energy and macronutrient content of the test meals were determined using the Philippine Food Composition Tables 1997 (FCT). All foods served were weighed based on the suggested serving portions in the *Pinggang Pinoy* food guide. Each test meal consisted of 1 cup cooked rice (160 g), ½ cup fish or lean meat (60 g), ¾ cup vegetables (90 g), ¾ cup fruits (60 g) and 1 glass drinking water (250 mL). Each test meal had a total weight of 620 g, and average energy content of 515 kcal. The test meals provided to the study participants over the 5-day test session period are presented in Table 2.

Calculation of energy density

Currently, there is a lack of consensus on the standard calculation method for dietary energy density published in literature. In this study, energy density is operationalized as the energy content of the test meal including water, divided by its total weight (kcal/g). The energy densities of the individual test meals served per day were calculated, and the

Table 2. Weight (g) and energy content (kcal) and composition of the 5-day breakfast test meals

Day	Food item	Weight (g)	Energy content (kcal)
1	Rice	160	577
	Chicken hotdog	60	
	Mushroom	45	
	Corn kernel	45	
	Banana	60	
	Water	250	
2	Rice	160	412
	Fish	60	
	Sweet potato tops	60	
	Tomato	30	
	Grapes	60	
	Water	250	
3	Rice	160	548
	Meat loaf	30	
	Egg	30	
	Lettuce	35	
	Cucumber	35	
	Tomato	20	
	Mango	30	
	Apple	30	
	Water	250	
4	Rice	160	514
	Egg	50	
	Cheese	10	
	Mushroom	50	
	Cucumber	40	
	Banana	60	
5	Rice	160	524
	Sausage	60	
	Lettuce	35	
	Cucumber	35	
	Tomato	20	
	Mandarin orange	30	
	Cantaloupe	30	
	Water	250	

average energy density for the meals served for 5 days was also derived and referred to as the mean energy density value.

Satiety ratings

Participants were instructed to rate their feelings of hunger (“how hungry do you feel right now?”) and fullness (“how full do you feel right now?”) in 100-mm VAS with words “not at all” and “extremely” anchored at the left and right ends, respectively. They completed VAS before eating (pre-prandial = 0 minutes) and consumed the entire test meals. Afterwards, they answered similar VAS on hunger and fullness over the 4-hour period following consumption of the test meals, at standard time intervals (30, 60, 90, 120, 150, 180 and 240 minutes).

Blood sample collection

Three (3) mL blood samples were drawn from each participant via saline lock at 0 minutes and at 30, 60, 120, 180 and 240 minutes postprandial. Blood sample collection

was done by a registered physician and a registered nurse trained on intravenous (IV) infusion. Blood samples were used to determine postprandial changes in plasma ghrelin concentration by radioimmunoassay (RIA) (Phoenix Pharmaceuticals, Inc., Burlingame, CA).

Data analysis

Hunger and fullness VAS measurements in millimeters (mm) were measured manually with the use of a standard ruler to determine specific hunger and fullness scores of participants. Mean VAS hunger and fullness ratings at each time point (30, 60, 90, 120, 150, 180 and 240 minutes) were then calculated using descriptive statistics. Similarly, mean ghrelin levels (pmol/L) at each time point (0, 30, 60, 120, 180 and 240 minutes) were calculated. Differences in mean hunger and fullness VAS ratings, and ghrelin levels between time points were determined using the General Linear Model (GLM) repeated measures analysis of variance (ANOVA) with time as within subjects factor and hunger and fullness VAS ratings, and ghrelin levels as dependent variables. This was followed by a post-hoc Bonferonni test to correct for multiple comparisons. SPSS (version 13) was used for all statistical analyses with significance set at p-value <0.05.

RESULTS

Energy density

The energy density of standardized test meals based on the healthy food plate model recommendations ranged from 0.83–0.93 kcal/g. The 5-day breakfast test meal cycle menu had a mean energy density value of 0.83 kcal/g (Table 3).

Table 3. Energy density of the test meals based on the healthy food plate model

Day	Energy density (kcal/g)
1	0.93
2	0.66
3	0.88
4	0.83
5	0.85
Average energy density	0.83

Hunger and fullness VAS ratings

There was a significant effect ($F_{1,9,22,9} = 53.53, p=0.000$) of time on mean hunger rating. As expected, mean hunger score was lower after consumption of the test meals and nadir was at 30 minutes postprandial. Mean temporal hunger ratings gradually increased with time but remained significantly lower ($p=0.025$) at 180 minutes postprandial than the pre-prandial state (0 minutes).

A significant time effect ($F_{1,62,19,46} = 43.84, p=0.000$) on mean fullness rating was also observed. Mean rating for feeling of fullness increased significantly ($p=0.000$) 30 minutes after intake of the test meals and gradually decreased thereafter but remained significantly ($p=0.008$) higher than the pre-prandial ratings until 180 minutes (Figure 1).

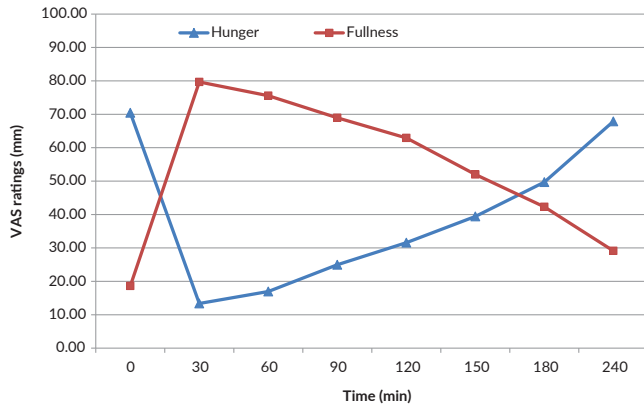


Figure 1. Mean ratings for hunger and fullness in 100 mm visual analogue scale (VAS) measured at different time points (0, 30, 60, 90, 120, 150, 180, 240 minutes), n=13.

Plasma ghrelin levels

There was a significant time effect ($F_{5,8}=5.55, p<0.05$) in the plasma ghrelin concentration of study participants. Ghrelin concentration was highest at pre-prandial (79.43 ± 75.83 pmol/L) but steadily declined after consumption of the test meals and stayed significantly ($p<0.001$) lower than the pre-prandial level at 240 minutes postprandial (30.21 ± 4.58 pmol/L) (Figure 2).

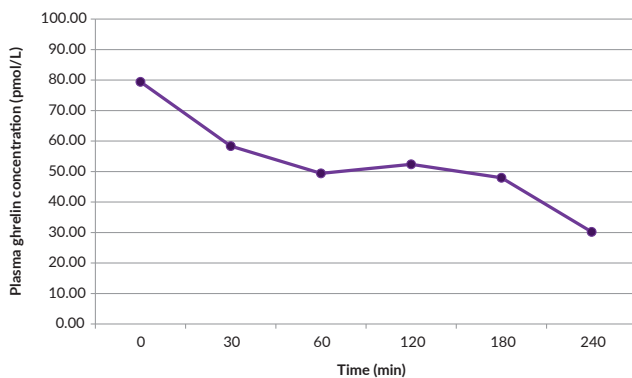


Figure 2. Mean plasma ghrelin concentration (pmol/L) measured at different time points (0, 30, 60, 120, 180, 240 minutes), n=13.

DISCUSSION

The present study showed that meals based on the healthy food plate model for Filipino adults (*Pinggang Pinoy*) have energy density values of 0.83-0.93 kcal/g. Consumption of these meals sustained satiety until 180 to 240 minutes postprandial.

In this study, the authors demonstrated the use of energy density in diet quality assessment. Currently, the concept of a nutritious diet lacks any standard definition or criteria and energy density has been suggested as a proxy indicator of diet quality.⁴ This proposition is based on the assertion

that diets with low energy density are associated with better nutritional quality because these diets are typically characterized by lower energy intake and higher intake of fruits, vegetables, legumes, fish and white meat.^{4,5,15-18} This can be explained by the fact that the energy density of a food or meal is primarily determined by its macronutrient composition and water content. The fat (9 kcal/g) and water (0 kcal/g) content of a food in particular, are important factors in the energy density value, and a straightforward strategy to lower the energy density of a meal is to reduce fat and incorporate foods that are rich in water like fruits and vegetables.¹⁹ The inclusion of more fruits and vegetables in the diet increases its total weight without causing large increments in caloric content, thereby lowering the energy density. The present study is a case in point of dietary energy density modification through increased fruit and vegetable consumption.

While energy density is potentially useful in diet quality assessment, there are challenges in standardizing its computation and defining the cut-off values. A study which examined different energy density calculation methods pointed to the importance of clearly defining treatment of beverages in the calculation in consideration of the purpose and the outcome interest of a particular study.³ Inclusion or exclusion of water in the calculation clearly influences the energy density values and this particular methodological issue was noted in the present study. The average energy density calculated by including the weight of water served with the test meals is 0.83 kcal/g but if water was excluded from the calculation, the energy density would have been 1.39 kcal/g. In the present investigation, it seemed valid and necessary to include water in the calculation of the energy density considering that the healthy food plate model for Filipino adults includes a glass of water as part of the meal recommendation. In addition, the present study was designed to investigate the effect of the overall meal combination in satiety and it is quite established that drinking water with a meal was reported to affect subjective feelings of hunger and satiety.²⁰ The lack of defined cut-off values to classify foods or diets according to energy density values also presents a challenge in this proposed system. One study which compared the effect of energy density in energy intake used cut-off ranges of 0.7 to 1.0 kcal/g for low energy density, 1.0 to 1.2 kcal/g for medium energy density, and 1.2 to 1.4 kcal/g for high energy density.¹⁸ The average energy density values of meals in this particular study differed by 20 percent between conditions. Hypothetically applying this classification in the present data together with the proposition that low energy density foods have better nutritional quality, it can be presumed that meals following the recommendations in the healthy food plate model have low energy density and have better quality. The validity of this categorization scheme however has not yet been tested in other studies and while the present study illustrates its usefulness, further research is needed to account for this

gap and to establish energy density as a metric standard of diet quality.

The current data also showed that consumption of the test meals based on the healthy food plate model sustained satiety in the short term. This particular finding can be attributed to increased fiber and water intake from vegetables and fruits, or to the reduction in the energy density of the meals, or to the combined effects of both. Unfortunately, this study do not provide sufficient information to assess the relative mechanistic effect of each of these factors but our data corroborates with the finding that diets with increased vegetable and fruit have significant effects in controlling hunger.¹⁰ The present data also lends additional support to the premise that foods with low energy density promotes satiety.^{10,21} It has been initially reported that energy density has a close linear relationship with gastric emptying and it appears that foods with low energy density consequently slow down the gastric emptying rate, thereby enhancing satiety.^{2,22} However, other findings are inconsistent with this assertion. Individuals who consumed similar amount of food (by weight) with varying energy density (low, medium, high) reported that feelings of hunger and fullness did not significantly differ across conditions.²³ Another study also noted that high energy density and low energy density elicited comparable effects on hunger and fullness.²⁴ Our findings demonstrate the usefulness of energy density as a proxy indicator of diet quality, but the inconsistency in published data indicates that the current understanding on how energy density affects satiety is limited, and further studies to understand the complex psychological and physiological mechanisms of this relationship are warranted.

In the present study, the state of satiety was determined by the combined use of subjective assessment (ratings of VAS hunger and fullness ratings) and a biomarker (temporal ghrelin profile). Theoretically, hunger and ghrelin profile closely overlap across time points but in this study, we noted that feelings of hunger increased earlier than the observed ghrelin levels.^{12,13} This means that participants already felt hungry after 3 hours of consuming the test meals (180 minutes postprandial) but they were in fact not “physiologically hungry” until after 4 hours (240 minutes postprandial). It is important to note that food- and time-related cues were not controlled in this study and participants were allowed to proceed to their workstations and do their normal day-to-day activities after consumption of the test meals in the laboratory. A study which determined voluntary meal initiation in the absence of any time- or food-related cues reported that the pre-prandial increase in ghrelin concentration occurred at a mean time interval of 359 minutes (\approx 5.9 hours) between a fixed lunch and a freely requested dinner.¹² It is possible that the earlier onset of feelings of hunger among the participants in the present study were influenced by the environmental cues of eating and eating patterns rather than the participants’ physiologic state of hunger. What is the implication of the

present finding in the context of the Filipino eating pattern? Generally, eating occasions for most Filipinos take place as many as five or six times a day, including breakfast, morning snack, lunch, afternoon snack, dinner and sometimes an after-dinner snack.²⁵ Filipinos are culturally habituated to take snacks in between regular meals and the present data pose challenges when taken in the context of maintaining energy balance. Based on the observed postprandial ghrelin levels, the consumption of a well-balanced breakfast with low energy density can sustain satiety for as long as 4 hours and hence, one may miss out snacking if regular meals (e.g. breakfast and lunch) are consumed at 4 to 5 hour interval. Unless energy compensation occurs on the next meal, calorie intake from snacks may increase total energy intake and it may consequentially contribute to positive energy balance.

The present study shows that by following the recommended quality and quantity of foods in the healthy food plate model, energy density can be lowered (and diet quality is improved) and consumption of these meals can sustain satiety. Dietetic professionals can utilize the present findings in the formulation of structured meal plans to guide and educate clients on food selection, food portion allocation, and time interval of eating occasions. Despite the limitations in the energy density concept, initial findings together with the data in the present study point to the robust effect of energy density not only on the nutritional quality of the diet but also on energy intake and satiety which can have potential applications in dietary strategies for weight management.

CONCLUSION

Results of the present study indicate that diets based on the recommendation in the healthy food plate model for Filipino adults have low energy density and its consumption sustained short-term satiety. Findings have practical implications in diet quality assessment, and regulation of appetite and energy intake.

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Statement of authorship

All authors have approved the final version submitted.

Authors disclosure

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