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# Influence of Fruit and Vegetable Intake on Satiety and Energy Intake: A Review

(Pengaruh Pengambilan Buah-buahan dan Sayur-Sayuran ke atas Tahap Kekenyangan dan Pengambilan Tenaga: Suatu Ulasan)

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ABSTRACT

*Fruit and vegetable are the natural foods that contained various nutrients vital for good health and help in weight loss by suppressing an individual's appetite. Therefore, this review aimed to investigate the acute effect of fruit and vegetable intake on satiety and energy intake. We included randomized controlled trial or experimental designs measuring fruit and/or vegetable intake on satiety using subjective appetite rating and appetite related hormone and energy intake among healthy adults, published in English-language. The use of extract, powder form or concentrated fruit and/or vegetable and animal study were excluded. Twelve studies were identified from Pubmed, Science Direct and Cochrane from the year 1995 to August 2017, consists of six studies on fruit and six studies on vegetable. This review discussed the preload of fruit and vegetable in promoting satiety and reducing the energy intake. Manipulating energy density rather than portion size was effective in reducing total energy intake and promotes satiety. Fruit and vegetable in solid form had a greater satiety effect and significantly reduce energy intake compared to liquid or pureed form. The variation in time interval between fruit and/or vegetable intake and the test meal may also account a significant effect on satiety up to 2 h and diminished 3 h onward. The satiety effect of fruit and vegetable would be beneficial in body weight management.*

*Keyword: Adult; energy intake; fruit; satiety; vegetable*

ABSTRAK

*Buah dan sayuran merupakan makanan semula jadi yang mengandungi pelbagai nutrien penting untuk kesihatan dan membantu dalam penurunan berat badan dengan menahan selera individu. Oleh itu, ulasan ini dijalankan bagi mengenal pasti kesan akut pengambilan buah dan sayuran terhadap tahap kekenyangan dan pengambilan tenaga. Kajian dipilih adalah berdasarkan kajian percubaan rawak terkawal atau kajian berunsur uji kaji yang mengukur pengambilan buah dan/atau sayuran ke atas tahap kekenyangan menggunakan skala kekenyangan subjektif dan hormon berkaitan selera serta pengambilan tenaga dalam kalangan individu dewasa yang sihat. Penggunaan ekstrak, serbuk atau pati buah dan/atau sayuran serta kajian ke atas haiwan dikecualikan. Dua belas kajian telah dikenal pasti hasil daripada pencarian di pangkalan data Pubmed, Science Direct dan Cochrane dari tahun 1995 hingga Ogos 2017. Enam kajian berdasarkan pengambilan buah dan enam kajian berdasarkan pengambilan sayuran. Tinjauan menunjukkan pengambilan buah dan sayuran lebih mengenyangkan dan mengurangkan pengambilan tenaga. Manipulasi ketumpatan tenaga berbanding saiz catuan makanan lebih berkesan dalam mengurangkan jumlah pengambilan tenaga dan lebih mengenyangkan. Buah dan sayuran dalam bentuk pepejal mempunyai kesan kekenyangan yang lebih tinggi dan mengurangkan jumlah pengambilan tenaga berbanding dalam bentuk cecair atau puri. Variasi selang masa antara pengambilan buah dan/sayuran dengan memberi kesan yang besar terhadap tahap kekenyangan dan ia bertahan sehingga 2 jam dan hilang selepas 3 jam. Kesan kekenyangan pengambilan buah dan sayuran mempunyai potensi dalam pengurusan berat badan.*

*Kata kunci: Buah; dewasa; kekenyangan; pengambilan tenaga; sayuran*

## INTRODUCTION

Living in an obesogenic environment through consumption of high energy density food and decrease in performing physical activities can impede a person's health and lead to overweight and obesity. The increasing rate of overweight and obesity worldwide are alarming as it does not only affect social health and wellbeing (Dixon et al. 2012; Xian et al. 2016), but also impact the environment and economic growth (Yach et al. 2006). Higher level of body adiposity among adult was linked to lower consumption of fruit and vegetable (Yu et al. 2018). Dietary strategies by sustaining satiety could be a comprehensive approach for body weight management as it may increase the compliance of individual to practise healthy eating (Daud et al. 2014; Weickert et al. 2008). It aids in reducing food intake whilst diminishing the sensation of hunger (Hetherington et al. 2013).

Currently, food with high satiety index score has received more attention (Brum et al. 2016). Satiety index

score refers to an area under the satiety response curve (AUC) for the test food in comparison to white bread as a standard and multiply by 100 (Holt et al. 1995). Fruits and vegetables rich in nutrients were categorized higher on satiety index (Fardet 2016). Foods with the higher value of satiety index will prolong satiety. The earlier idea was conceptualized by Blundell et al. (1987) in which sensation of satiety are more than just the metabolic effect of nutrients in the gastrointestinal tract. Several researches have suggested the idea on the effect of cognitive and sensory cues based on food's sight and smell as well as oro-sensory experience of food in the oral cavity such as taste and texture on satiety (Halford & Harrold 2012; McCrickerd & Forde 2016; Van Kleef et al. 2012).

Satiety level may vary in each individual and is affected by multiple factors including age, gender, body mass index and physical activity. Ageing resulted the individuals to experience less hunger (Chapman et al. 2012; Hays & Robert 2006). It was found that female subjects reported higher satiety and fullness rating as compared to men. However, one study reported the opposite result where female subjects in menstruation period tend to have a higher postprandial hunger rating than during ovulation period (Greary 2000). This is due to the difference in concentration of sex hormones such as estradiol. Higher level of estradiol increase the satiating power initiated by the endogenous cholecystokinin (Gregersen et al. 2011). Individuals with sedentary lifestyle also tend to have a higher rating of hunger compared to hard/moderate exercisers (Gregersen et al. 2011).

Multiple peptides synthesized by gastrointestinal tract may also affect appetite regulation. These include ghrelin as orexigenic peptide and anorexigenic peptides include peptide YY, pancreatic polypeptide, glucagon-like-peptide 1, oxyntomodulin and cholecystokinin (Perry & Wang 2012). Ghrelin showed positive correlation with hunger (Kojima & Kangawa 2008) whilst other anorexigenic hormones may suppress hunger and make individuals feel full (Holst 2007; Neary & Batterham 2009).

A study by Rolls et al. (2010) has reported that filling up with fruit or vegetable before meal or with meal may reduce energy intake. One possible reason is due to the fiber content that makes individual to feel full longer. In addition, fruit and vegetable are low in energy density which causes the individuals to feel full on fewer calories and may stay full longer as compared to other foods consumed in the same amount. It was reported by de Oliveira et al. (2008) that fruits can reduce energy intake and body weight as compared to other food regardless of the same energy content. Systematic review by Kaiser et al. (2014) found no significant effect of increasing fruit and/or vegetable intake in isolation of other interventions for more than 8 weeks on body weight whilst a small reduction in body weight was found in a recent review among those who consumed more fruit and vegetable without any dietary advice and modification (Mytton et al. 2014). This variation of results was due to the absence of specific guideline in promoting the increment of fruit and vegetable intake in each study. Therefore, this article has reviewed the effect of fruit and vegetable intake on satiety by controlling food intake and appetite based on the specific study design. It can be an indispensably helpful guideline for body weight management as well as practices of healthy eating.

## Materials and Methods

Relevant studies were identified through PubMed, Science Direct and Cochrane database published from January 1995 to August 2017. The articles published prior to 1995 were excluded as methodology of research on satiety has been improved in recent years. The keywords used were 'Fruit' or 'Vegetable' AND 'Satiety' or 'Satiation' or 'Fullness' or 'Appetite' or 'Energy Intake' or 'Satiety Hormone' or 'CCK' or 'Ghrelin' or 'Leptin' or 'Insulin' or 'PYY' or 'GLP-1' or 'GIP' or 'Orexin' and limited to human, adult, clinical trial, randomized control trial and those published in English language only. The studies were narrowed down to only those using whole fruit and/or vegetable without any added food components such as carbohydrate, fat and protein. Intervention based solely on powder, extract or concentrated fruit and vegetable were also excluded. Eligible studies reported the subjective appetite rating or energy intake and hormone related to appetite and satiety was included. Any studies involving animals and children or subjects with genetic conditions that may affect their dietary intake and those with chronic diseases such as diabetes, cardiovascular disease and chronic kidney disease were excluded. Intervention that sought to manipulate any dietary components and to promote weight loss was also excluded as it may overshadow the effect of fruit and vegetable on satiety.

## Results

From a total of 1671 publications only twelves studies met all the selection criteria and were included in the present review. Six out of 12 studies examine the effect of fruit on satiety whilst another 6 studies examine satiety effect of vegetable. The summary tables are shown in Tables 1 and 2 for satiety effect of fruit and vegetable, respectively. All of the studies measured both the effect of fruit and vegetable on subjective appetite rating and energy intake except for a study on fruit intake only to measure the effect of fruit on satiety hormone. Only two studies of fruit intake and one study vegetable reported on satiety hormone. Majority of subjects were overweight and obese adults aged 18 to 65 years old. Only one study on fruit and a study on vegetable involved subjects with normal BMI. Most of the studies include both male and female subjects, except for four studies were among female subjects and a study on male subjects.

TABLE 1. Effect of fruit intake on satiety

| Author, Year | Sample population | Study design | Intervention | Results | | |
|---|---|---|---|---|---|---|
| | | | | Satiety | Energy intake | Satiety hormone |
| Flood-Obbagy & Rolls (2009) | N= 58<br>18-45 years old<br>18.0-40.0 kg/m$^2$ | Crossover repeated measure | Preload of apple or apple puree or apple juice or apple juice with added fiber or no preload | Apple> apple puree> both apple juice><br>no preload | Apple< apple puree < both apple juice<<br>no preload | - |
| Farajian et al. (2010) | N=30<br>18-50 years old<br>18.5-24.9 kg/m$^2$ | Randomized within-subject crossover | Preload of dried prune or white bread | Dried prune > white bread | No significant difference | - |
| Wien et al. (2013) | N=30<br>25-65 years old<br>20.0-25.0 kg/m$^2$ | Randomized single -blind crossover | Meal with inclusive avocado or added avocado or with no avocado | Inclusive avocado> added avocado><br>no avocado | No significant difference | Insulin level was higher in control and added avocado tests meal compared to inclusive avocado<br>No significant difference was found for glucose |
| Houchins et al. (2013) | N=34<br>18-38 years old<br>18.5-40.0 kg/m$^2$ | Randomized crossover, two arm study | Preload of fruit or no preload, and preload of fruits juice and no preload | No significant difference | Preload of solid fruit < fruit beverage | - |
| James et al. (2015) | N=15 women<br>18-25 years old<br>26.6 $\pm$ 2.6 kg/m$^2$ | Crossover repeated measure | Snack on berries or confectionary with the same energy content 60 min before dinner | No significant difference | Snack on berries < confectionary | - |
| Kaliora et al. (2017) | N=10<br>20-60 years old<br>18.5-24.9 kg/m$^2$ | Randomized crossover | Breakfast meal with either 74 g of raisins or 50 g of glucose diluted in a glass of water | - | - | Low level of ghrelin after raisin consumption compared to glucose solution at 120 and at 180 min post ingestion<br>GIP levels lower in raisin trial compared to glucose trials at 60 and 120 min<br>No significant differences were found for glucose, insulin, apelin, obestatin and GLP-1 in both trials |

TABLE 2. Effect of vegetable intake on satiety

| Author, Year | Sample population | Study design | Intervention | Results | | |
|---|---|---|---|---|---|---|
| | | | | Satiety | Energy intake | Satiety hormone |
| Rolls et al. (2004) | N=50 women<br>19-45 years old<br>18.5-39.9 kg/m$^2$ | Within-subject cross over | Preload of 150 g salad with energy density (0.33, 0.67 or 1.33 kcal/g) or preload 300 g salad with energy density (0.33, 0.67 or 1.33 kcal/g) or no salad | Large portion of salad > small portion of salad | High portion size of salad < less portion size of salad<br>No significant different was found for the energy density | - |
| Rolls et al. (2010) | Addition:<br>N= 53<br>Substitution:<br>N= 48<br>20-45 years old<br>18.0-40.0 kg/m$^2$ | Cross over repeated measure, two arm study | Addition of vegetable in meal<br>Alteration of energy density of meal by substitution of vegetables | No significant diference<br>No significant difference | No significant difference<br>Substitution of vegetables by 180 to 270 g reduce energy intake | - |
| Chang et al. (2010) | N= 30 women<br>20-40 years old<br>18.0-30.0 kg/m$^2$ | Cross over repeated measure | Consumption of parboiled vegetable rice or parboiled normal rice with side dishes | Parboiled vegetable rice > parboiled normal rice<br>No difference after 3 hour of test meal | Parboiled vegetable rice < Parboiled normal rice<br>Energy intake was low after 4 hours in parboiled vegetable rice than parboiled normal rice | - |
| Blatt et al. (2011) | N=48<br>20-45 years old<br>18.0-40.0 kg/m$^2$ | Cross over repeated measure | Substitution of vegetable reduce energy density for each meal (Breakfast, Lunch and Dinner) by 100%, 85% and 75% of energy density | No significant difference except during breakfast, 75% condition > 100% | Total energy intake in 75% condition < 85% < 100% | - |
| Roe et al. (2012) | N=55 women<br>20-45 years old<br>18.0-40.0 kg/m$^2$ | Cross over repeated measure | Preload ad libitum salad or preload of fixed amount of salad or ad libitum salad with meal or fixed salad with meal or no salad | Preload of salad and salad with meal > no salad | Fixed salad and ad libitum salad with meal < No salad<br>Fixed salad < ad libitum salad | - |
| Zhu et al. (2013) | N= 20 male<br>18-50 years old<br>20.0-29.9 kg/m$^2$ | Randomized cross over repeated measure | Liquid-solid meal (LS) (Chicken broth with whole piece of vegetables or Liquid Meal (LM) (Chicken broth with small piece of vegetable) 3 hour before lunch (test meal) | Liquid meal > liquid-solid meal | No significant difference | No significant difference on ghrelin<br>Hormone CCK was higher at 90 minutes and 120 minutes in LM compared to LS<br>Insulin level was higher in LM than LS at 30 and 45 min |

### EFFECT OF FRUIT AND VEGETABLE ON SUBJECTIVE APPETITE RATING

Subjective appetite rating scale by using Visual Analogue Scales (VAS) is one of the most common methods used in measuring satiety. It provides a greater insight for interpretation of eating behaviour and allows measurement of eating motivation (Drapeau et al. 2005; Flint et al. 2000). A variety of studies have examined the satiety effect of fruit consumption either the fruit was served before meal, with meal or as a snack prior to main meal. In this review, three out of six studies reported a significantly higher score of satiety among those subjects consume fruit as compared to those without fruit. Consuming fruit before meal facilitate in suppressing appetite which in turn cause individual to feel full longer than those who having a meal without fruit (Flood-Obbaggy & Rolls 2009) (Table 1). Farajian et al. (2010) studied 30 subjects in a crossover design where the subjects were provided a preload of either dried prune or white bread matched with energy content prior to lunch test meal. Subjects who had a preload of prunes reported a significant less hunger and feel full more than white bread at all time points. A study by Wien et al. (2013) examined the effect of avocado on satiety. Avocado was either added in a lunch test meal (AA) or inclusively added in a test meal by reducing energy content (AI) to match with the control which is without avocado (C). No significant difference was found among 3 interventions on hunger and satiety rating. However, additional avocado (AA) scored higher satisfaction and scored less desire to eat compared to those without avocado ($p<0.05$). This indicated that adding avocado may influence post-ingestive satiety over a subsequent 3 and 5 h period. Inclusive avocado (AI) with match energy content with control group also showed a tendency of higher score of satisfaction as compared to control group ($p=0.07$).

In contrast, two studies (Houchins et al. 2013; James et al. 2015) did not find such an effect. No significant difference was found between preload of fruit either in solid or beverage form and control (no fruit) on satiety. Nevertheless, a higher satiety rating was reported among those consume preload of whole fruit compared to preload fruit beverage (Houchins et al. 2013). James et al. (2015) found no difference in satiety for both trials (preload of 160 g mix berries or confectionary (19.4 g of sweets) match with energy content). Nevertheless, it was noted that preload of mix berries was more palatable than confectionary. Foods with high palatability was associated with the fast return of hunger and desire to eat (Srubbs et al. 1996).

Table 2 summarizes six studies based on the effect of vegetable consumption on satiety. All studies have manipulated several parameters including energy density, physical form of vegetable or either vegetable were served before meal or were served inclusively with the meal. Out of six studies, two studies examine the effect of vegetable intake before the meal and other studies involved vegetable intake with meal. A study involving 55 women examined the effect of the consumption of *ad libitum* or fixed amount of salad before meal, *ad libitum* or fixed amount of salad with meal or meal with no salad (Roe et al. 2012). Subjects scored less hunger and more satiety for a fixed or *ad libitum* salad compared to without salad ($p<0.001$). However, no significant effect of timing of salad either consume before meal or with meal was identified. Whilst, the subjects reported to feel less hunger and more satiety when consume fixed salad than consume salad in *ad libitum*. Rolls et al. (2010) also found a significant effect of vegetable consumption on satiety whereby consuming large portion of salad (300 g) was more satiety than small portion of salad (150 g) and no salad, respectively.

Out of four studies involved consumption of vegetable with the meal, only one study showed no significant difference between meals served with vegetable and without vegetable on satiety (de Oliveira et al. 2008). Another study found that energy density of food was manipulated by adding vegetable in different portions (Blatt et al. 2011). Nevertheless, this study reported the same result whereby substitution with vegetable in three main meals did not affect satiety except during breakfast. Subject reported to feel more satiety after taking more puree vegetable with 75% energy density of meal compared to 100% of energy density (Blatt et al. 2011). Small particle size of vegetable (liquid meal) was also found to be more satiety compared to large particle size (liquid-solid meal) (Zhu et al. 2013). It opposed the initial hypothesis of this study where liquid-solid meal would be more satiety compared to liquid meal as it requires mastication and will take more longer to eat. The slower eating rate resulting in higher satiety (Kokkinos et al. 2010). However, Zhu et al. (2013) did not measure the time taken by the subject to complete their meal that will contribute to the difference in feeling satiety among subjects. Furthermore, the addition of vegetable in parboiled rice resulted in more satiety than parboiled rice without vegetable (Chang et al. 2010).

It was reported that subject characteristics such as age and gender were not significantly associated with energy intake (Blatt et al. 2011; Flood-Obbagy & Rolls 2009; Rolls et al. 2010). However, other studies (Farajian et al. 2010; Houchins et al. 2013) did not report the mean difference of satiety and energy intake between male and female subjects.

### EFFECT OF FRUIT AND VEGETABLE ON ENERGY INTAKE

Assessment of the amount of energy intake at a subsequent eating event or known as subsequent energy intake also being used to measure satiety (Blatt et al. 2011; de Graaf et al. 1992; Geliebter et al. 1988). Studies have examined the influence of fruit or vegetable intake on satiety. The study design of each study in this review are similar whereby fruit and vegetable were given either before meal or with meal. In this review, three out six studies on fruit showed less energy intake after consumed fruit as compared to without fruit (Flood-Obbagy & Rolls 2009; James et al. 2015) and less energy intake when consume whole fruit than fruit beverage (Houchins et al. 2013). No significant

difference of energy intake was found in two studies (Farajian et al. 2010; Wien et al. 2013). Energy intake after the consumption of dried prune has no difference with trials of white bread (Farajian et al. 2010). Wien et al. (2013) also reported the same finding where subjects who consumed added avocado or inclusively added avocado in meal showed no significant difference in subsequent energy intake as compared to without avocado.

In this review, satiety rating for vegetable intake either with meal of before meal cannot be used to predict the subsequent energy intake since both studies (Blatt et al. 2011; Rolls et al. 2010) showed no significant difference in satiety rating while the meal intake reduced significantly. Preload of fixed amount of vegetable reduced meal intake more than *ad libitum* intake of vegetable. This is due to the differences in the amount of salad consumed in fixed amount and *ad libitum* group. It was found that intake of salad for *ad libitum* were less compared to fixed salad either before or with meal (Rolls et al. 2014). Besides, there was a less energy intake when consuming a preload of large portion of salad (300 g) compared too small portion of salad (150 g) but no significant difference was found when energy density was manipulated (Rolls et al. 2010). Out of four studies that includes vegetable intake in test meal, a study that included vegetable in the parboiled rice significantly reduced the subsequent energy intake (Chang et al. 2010). As energy density was reduced, the lower the energy intake consumed by an individual. A study has been conducted in manipulating energy density for three main meals; breakfast (carrot bread), lunch (macaroni and cheese) and dinner (chicken and rice casserole). Subjects were provided with 100% energy density (standard meal), 85% energy density of the standard and 75% energy density of the standard. Energy density was manipulated by increased the amount of pureed vegetable in each meal to 3 or 4.5 time than the standard meal. It was reported that subjects consumed less 202 ± 60 calories in 85% energy density and less 357 ± 47 calories in 75% energy density as compared to standard meal (100% energy density condition) which was 3117 ± 132 kcal (Blatt et al. 2011). Rolls et al. (2010) reported a significant reduction in meal energy intake (83 ± 14 kcal or equivalent to 14 ± 3%) as energy density of meal was reduced from 0.8 to 0.4 kcal/g and portion size of vegetable was increased from 180 to 270 g. No significant difference was found as the portion was further increased from 270 to 360 g. Besides, preload of difference particle size of vegetable in soup also had no significant difference on subsequent energy intake (Zhu et al. 2013).

## EFFECT OF FRUIT AND VEGETABLE ON APPETITE HORMONE

There was limited study on the effect of fruit and vegetable intake on appetite related hormone. Only two studies examine on the effect of fruit intake on appetite hormone. A significant rise of insulin level was found among those consume inclusive avocado or added avocado, 37% and 22%, respectively, ($p$<0.05) 30 min after the lunch test meal (Wien et al. 2013). However, after three hours, the level of insulin was lower among subjects consumed inclusive avocado as compared to control and added avocado, respectively. No significant difference was found for glucose concentration for three trials. In a recent study, Kaliora et al. (2017) reported a significant low level of ghrelin after the consumption of raisin as compared to glucose solution at 120 and 180 min post ingestion. Gastric Inhibitory Polypeptide (GIP) level was also lower in raisin trials compared to glucose trials at 60 and 120 min. GIP level may peak as there is an active absorption of glucose (Fujita et al. 2009; Wachters-Hagedoorn et al. 2006). In this study, the raisin trials showed a delay of GIP response indicate that there was a delayed of glucose absorption as compared to consuming glucose concentration. One possible explanation was due to the fiber content which leads to a slower digestion and absorption by delaying gastric emptying or shorten bowel transit time. However, no significant difference was found for glucose, insulin, apelin, obestatin and GLP-1 in both trials.

Only one study involve vegetable had reported the effect of vegetable intake on satiety hormone. It was found that, there was no significant difference on ghrelin after consuming whole piece of vegetable in a broth, liquid solid meal (LS) or liquid version of the same ingredients, liquid meal (LM) in the meal (Zhu et al. 2013). However, CCK level was higher as subjects consumed LM than LS at 90 and 120 min postprandial. The potential cause was due to the size of particle where the smaller the size of particle of vegetable the larger the surface area intact with small intestine and causing more CCK hormone to be released.

## EFFECT OF ENERGY DENSITY AND PORTION SIZE ON SATIETY AND ENERGY INTAKE

Energy displacement by alteration of energy density of food was suggested as the best method to decrease or maintain body weight (Ello-Martin et al. 2007). Lower energy density foods provide less energy per gram of food, therefore eating more will not contribute too much calorie intake compared with the intake of high energy density foods (Monsivais & Drewnowski 2007). Most fruit and vegetable are low in energy density due to the high amount of water content that increases the volume and weight of the food itself (Flood-Obbagy & Rolls 2009). Many studies used the strategy of adding portion size of fruit or vegetable in meal in order to increase volume of foods and reduce the energy (Bell et al. 2001, 1998; Rolls et al. 1999). Study by Wien et al. (2013) reported that addition of either avocado in meal or substitution of avocado in meal by reducing the amount of salad dressing and cookies (avocado inclusive) have increased the satiety and reduce the desire to eat over 3 and 5 h in overweight and moderately obese adults, respectively. Furthermore, addition of avocado reduce meal energy intake during lunch as compared to control (without avocado). However, there is no mean difference

between three lunch test meal on subsequent *ad libitum* dinner meal due to long duration between lunch and dinner meal which was 5 h time interval.

In this review, three out of six studies used vegetables inclusively with main meal thus manipulated the energy density of the main meal. As energy density of test meal decrease by addition of vegetable and reduction of meal size of other food components, the energy intake decreases (Blatt et al. 2011). In two arm study, Rolls et al. (2009) found no significant difference in total meal and energy intake as vegetable was added in meal whereas total energy intake was reduced significantly as the portion size was increased to match with the reduction in energy density. Addition of vegetable by increase portion size of vegetable from 180 to 360 g did not significantly affect total energy intake. This result in line with substitution study in which the reduction of energy density of food by reducing portion size of meat and grain and increase portion size of vegetable did not affect overall meal energy intake. However, the study found a significant reduction of meal energy intake as portion size of vegetable was increased from 180 to 270 g. In addition, Chang et al. (2010) found the intake of parboiled vegetable rice resulted in more satiety as compared to parboiled rice and thus reduce total energy intake. This is due to the parboiled vegetable rice had larger volumes than parboiled rice when both were compared by weight. However, there was no significant difference in amount of side dishes taken by subjects in both interventions. As the energy density was changed, the percentage of macronutrients also differs and might affect satiety (Clegg & Shafat 2010; Wikarek et al. 2014). However, none of the studies from this review reported any significant effect of other macronutrients on satiety. For example, parboiled vegetable rice contains less protein (2.1 g) and carbohydrate (18.9 g) per 0.86 kcal/g as compared to a match volume of normal parboiled rice with 2.7 g of protein and 31.4 g of carbohydrate per 1.42 kcal/g (Chang et al. 2010). Rolls et al. (2004) also found, there was a significant effect of energy density rather than variation in fat content (14% to 67%) on satiety.

### PHYSICAL FORM OF FRUIT AND VEGETABLE ON SATIETY

Many studies also manipulated the physical form of fruit in order to optimize the satiety effect (Almiron-Roig et al. 2003; Mattes 2006). Previous studies showed that consuming solid form of fruit resulted in more satiety than in liquid form (Pan et al. 2011). Based on Flood-Obbagy and Rolls (2009), preload of whole apple led to more satiety as compared to applesauce, apple juice, apple juice with fiber and no preload. Fiber might be one of the factor that affect the satiety level of an individual (Slavin 2005). However, another study found no effect of fiber on satiety (Flood-Obbaggy & Rolls 2009). The other possible explanation might be due to the number of mastication. Increase mastication of food would initiate cephalic-phase response by affecting digestion and metabolism thus affect food intake (Li et al. 2011).

In contrast, Zhu et al. (2013) found an opposite result whereby vegetable in liquid form resulted in more satiety than in solid form. However, this study has some limitation as how much mastication effort was required to induce satiety was not reported. Besides, this study did not show the gastric transit time. Previous study by Kong and Singh (2008) proved that foods with larger particle size can slower the rate of gastric emptying. Of all, none of the studies included in this review measures the masticatory effort on satiety. The time interval between test meal and subsequent meal intake which is longer (three hours) may reduce its effect on satiety. Satiety hormone such as CCK also found to be higher among subjects who consumed liquid meal compared to solid meal, suggested that the smaller particle size of test meal increase the surface area intact with duodenum where the CCK will be released (Ledebeor et al. 1999; Maljaar et al. 2012). However, there was no significant difference of ghrelin concentration between both interventions either in liquid or solid form.

## DISCUSSION

Preload or added fruit and vegetable were likely to show a significant increase on satiety and reduction of energy intake. Most of the studies only measured satiety and food intake during the meal without taking into account the food intake for the whole day, thus limiting the data on the long term effect of fruit and vegetable consumption on the subsequent energy intake and satiety. Apart from using visual analogue scale (VAS), there are several approaches to assess satiety including labelled magnitude scale (LMS) (Zalifah et al. 2008) and computer-based approach (Farah et al. 2012).

Fruits and vegetables are very nutritious and packed with vitamin and minerals that can be eaten throughout the day. Nonetheless, some general guidelines should be highlighted to fully benefit our health and optimized the potential role of fruit and vegetable in managing body weight (Harden et al. 2009). Even though fruit and vegetable help to fill the stomach with less calorie, the emphasis on portion size and how they are prepared should be considered. Whole fruit is much better compared to juice since most of the natural fiber is removed during process and extra calorie from added sugar will increase the total calories. Besides, more chewing effort needed for the whole fruit, thus induce satiation through cephalic-phase respond. A small serving of dried fruit can be a choice for a healthy snack and alternative for high energy dense foods if consume in a small serving size. If taken too much, dried fruit that have high sugar content will increase the total calorie, promote weight gain and even cause a sharp rise on blood sugar (Alinia et al. 2009; Khairuddin et al. 2017). The timing of fruit intake might also make a significant difference on satiety. To date, no study has been designed to find out the effectiveness of fruit intake either before or after meal on appetite control as well as blood glucose control especially among those with impaired glucose. This

would be beneficial for the patient in controlling their blood glucose control when including fruit as part of their diet.

The study design of each study was heterogeneous in terms of study population, size and duration between preload and test meal. A wide gap of age among subjects would affect the overall results (Harden et al. 2009). However, studies showed that socio demographic factors did not have strong impact on the satiety rating and subsequent energy intake. Manipulation of portion size and energy density of fruit and vegetable would be an effective strategy in promoting satiety as well as reducing overall energy intake (de Oliveira et al. 2008). Time interval between preload and test meal may also affect satiety (Luhovvy et al. 2007; Veldhorst et al. 2009). However, as the energy density was manipulated, the effect of time interval fades out. Preload of fruit and vegetable in between 15 min to 1 h has effectively increased satiety and reduced subsequent meal intake, however, there was no effect on satiety found after an interval of 3 h onwards.

The time delay of preload of protein, maltodextrin or water (30, 60 and 120 min) had no effect on subsequent meal intake (Chungchunlam et al. 2012). Nevertheless, the time interval between preload and test meal might also be affected by variation of macronutrients. It was found that the ingestion of carbohydrate and protein may supress hunger within 60 min whilst proteins showed more suppressive effect where it can last longer. Meanwhile, fat was reported to be the least suppressive effect compared to protein and carbohydrate, respectively (Fischer et al. 2004). The physical form of food also may affect the effect of time interval on satiety and subsequent meal intake. The amount of vegetable and the threshold of masticatory effort are still unclear and need to be further investigated.

There is a need in emphasizing a concise and systematic study design to formulate effective strategies in controlling appetite and body weight management by manipulating the consumption of fruit and/or vegetable in individuals' diet. A concise study design should be conducted such as controlling the type of fruit and vegetable consumed since some of the previous studies failed to get the significant result as the food items used during intervention did not match between groups (Houchins et al. 2013). In addition, further study should be done precisely with specific preparation of fruit and vegetable in term of cooking method and either it is served with skin or not, since the fiber content might differ and can make a significant change in overall result.

## Conclusion

This review has proven that consumption of fruit and/or vegetable either before meal or with meal may promote satiety and are beneficial in reducing energy intake. There are three studies on fruit intake and four studies on vegetable intake which reported a significant effect on satiety. Meanwhile, three studies on fruit intake and five studies on vegetable intake found a significant reduction of subsequent energy intake. Measurement of appetite hormone may aid in measuring the satiety level of an individual precisely. Factors such as fiber content, physical form, particle size, timing and energy density of fruits and vegetables, time interval between fruit and/or vegetable intake and test meal may influence the satiety response. It can be as part of strategies for weight management in controlling appetite and food intake by manipulating these factors.

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