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Orange pomace fibre increases a composite scoring of subjective ratings of hunger and fullness in healthy adults

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This research was sponsored by PepsiCo Inc., United Kingdom. Abbreviation used: AOAC, Association of Official Agricultural Chemists; AVAS, adaptive visual analogue scale; GCP, Good Clinical Practice; HD-OPF, high dose orange pomace fibre; LD-OPF, low dose orange pomace fibre; LSMs, least square means; OJ, orange juice; OPF, orange pomace fiber; VAS, visual analogue scale; WO, whole Orange.

ABSTRACT

Dietary fibre has been shown to increase subjective satiating ratings. However data from human trials has produced mixed results, possibly due to different types of fibre which have diverse physicochemical properties and gastrointestinal transit behaviour. The aim of the study 1 was to investigate whether orange juice (OJ) with 5.5 g of added orange pomace fibre (OPF) was as satiating as whole orange (WO, chopped to a liquid form) compared with OJ. Study 2 was to evaluate the dose-dependent satiating effect of OPF delivered in an orange-flavoured beverage. Both studies were randomized, controlled, double blind, cross over in design with 4 intervention arms in study 1 including OJ, OPF, WO, and water, and 3 arms in study 2 : orange-flavored beverage with low (2.5 g) and high (5.5 g) dose of OPF (LD-OPF and HD-OPF), and orange-flavored beverage without fibre (Control**).** Volunteers were asked to response to 8 questions relating to hunger, fullness, desire to eat, thirst and discomfort by visual analogue scale (VAS) for each question. Differences were detected in least squares mean estimates of composite satiety scores and each individual question with statistical modelling to adjust for differences in baseline scores. Addition of 5.5 g OPF either to OJ or to orange-flavored beverage significantly increased the composite satiety scores compared with OJ ($P<0.0001$) or Control ($P<0.0001$), and the effect was comparative to WO. LD-OPF showed some satiating effect (less desire to eat) compared with Control ($P=0.038$), though less effective than HD-OPF ($P=0.043$). In conclusion, the addition of OPF to OJ was as effective at increasing satiety as WO consumption compared with OJ; and there was a trend of dose-dependent effect of OPF on satiety compared with the control.

Key words Dietary fibre, VAS, satiety, orange juice, composite satiety scores

1. Introduction

Fruits and vegetables were reported to increase subjective satiety ratings and promote satiety as measured by subjective ratings of hunger and fullness, and it has been shown that eating fruit before a meal can reduce overall energy intake (Flood-Obbagy & Rolls, 2009). A satiety index of common foods produced in one study found that fruits had the highest average satiating index score, in particular oranges and apples, which were twice as satiating as measured by subjective ratings of hunger and fullness as white bread (Holt, Miller, Petocz, & Farmakalidis, 1995). Additionally, the degree of satiation can vary depending on fruit form. Two separate studies found eating a whole apple reduced food intake and had a more satiating effect as measured with VAS compared to pureed apple or apple juice (Bolton, Heaton, & Burroughs, 1981; Flood-Obbagy & Rolls, 2009). Some other studies (Birketvedt, Aaseth, Florholmen, & Ryttig, 2000; Bolton et al., 1981) also found that oranges and grapes eaten whole evoked considerable more satiety than the equivalent amount of juice. This satiating effect may be due to the fibre present in high quantities in whole fruit, and also the longer time to consume the whole fruit compared with fruit juice (Flood-Obbagy & Rolls, 2009).

A study with 74 adults found that adding pectin, a soluble fibre, to orange juice significantly increased subjective satiety (Tiwarya, Warda, & Jacksona, 1997). In contrast no difference in appetite ratings were reported after consumption of apple juice with added fibre compared to apple juice alone (Flood-Obbagy & Rolls, 2009). Furthermore addition of 15 g low molecular weight fibre, an enzyme-hydrolyzed arabinoxylan from wheat and an intact arabinoxylan from flax, to a ready-to-eat cereal did not affect perceived appetite or subsequent energy intake despite of differences in satiety hormone signalling in overweight females (Lafond, Greaves, Maki, Leidy, & Romsos, 2015). These varied results are potentially due to the different types of fibre used with diverse physicochemical and gastrointestinal transit behaviour, dosage, subjects and delivery form incorporated in these studies (Guérin-Deremaux et al., 2011; Lafond et al., 2015; Wanders et al., 2011) In a systematic review of randomised controlled trials fibres characterized as more viscous reduced appetite ratings and acute energy intake compared to less viscous fibres (Wanders et al., 2011). When differentiated by solubility of fibre the same review reported that 48% (n=46) of studies using more soluble fibres saw a reduction in appetite ratings compared to 25% (n=12) for less soluble fibres.

In the current paper, orange pomace fibre (OPF), the edible components of whole orange leftover from orange juice manufacture, was subjected to particle size reduction and was investigated for its effects on short-term subjective satiety ratings of hunger and fullness in two studies. The first study evaluated whether orange juice (OJ) with 5.5 g of added OPF was as satiating as whole orange (WO, chopped to a liquid form) compared with OJ; the second study was conducted to evaluate the dose-dependent effect of orange pomace delivered in the orange-flavoured beverage on satiety.

2. Methods

The studies were performed at the Hugh Sinclair Unit of Human Nutrition at the Department of Food and Nutritional Sciences, University of Reading, UK. Both studies were registered as a clinical trial (NCT02116023 for study 1, NCT02288624 for study 2) and were conducted according to the Declaration of Helsinki following Good Clinical Practice (GCP). Professor Ian Rowland and Jeremy P. E. Spencer were the Principal Investigators of study 1 and Professor Julie A Lovegrove was the Principal Investigator of study 2. Both studies were sponsored by PepsiCo Inc. and were given a favourable opinion for conduct by the University of Reading's Research Ethics Committee. All volunteers signed a consent form before commencing the study.

2.1 Study subjects

Volunteers were recruited from the University of Reading and surrounding area by use of the Hugh Sinclair Unit volunteers' database and poster advertisement within the university between the 8th May 2012 and the 19th September 2012 (study 1) and between the 11th March 2014 and the 30th April 2014 (study 2).

For both studies men and women (women were post-menopausal in study 1 and either post-menopausal or taking contraceptive pills in study 2) were recruited. They were in general health assessed by a lifestyle and health questionnaire, aged 21-65 inclusive with a body mass index (BMI) 18.5 - 27 kg/m^2 inclusive, no medically prescribed or slimming diet, used to eating 3 meals a day, intense sporting activities ≤ 10h/week, and alcohol consumption ≤21 units/week. Subjects were excluded if smokers, disliked or had intolerance to test products, had possible eating disorder measured by SCOFF (Sick, Control, One stone, Fat and Food) questionnaire (score > 1) and any one factor score of three-Factor Eating Questionnaire > 14, or reported medical treatment that may affect eating habits/satiety. In study 1, a total of 26

subjects were screened and 25 were eligible and randomised to the study, and 24 completed with one drop-out because of headache unrelated to the study products. A total of 31 subjects were screened and 30 were eligible and randomised, and completed without drop-out in study 2, among which 10 took part in study 1. It was one year and half between studies.

2.2 Study treatments

Study 1: There were four treatments. Orange juice (OJ), OJ with 5.5 g of added orange pomace fibre (OPF), peeled and chopped whole orange (WO), and water. Treatments were matched on weight (255g) and total sugars, except for water (table 1). As the whole orange was consumed fresh values provided are for a whole orange (raw, all commercial varieties) from the USDA nutrient database for standard reference which are likely to vary slightly due to seasonal and varietal differences. All of the products in the study were provided in liquid form of 240 ml (255 g equivalent whole orange was peeled and chopped or blended to liquid) contained in aluminum canisters for the purpose of blinding the volunteers and researchers. The products were stored frozen at -20 ºC before use. OJ and WO were provided by PepsiCo Inc., and OPF and Control were prepared in the pilot plant at the Department of Food and Nutritional Sciences at University of Reading according to good manufacturing practice and by personnel certified in good food safety and hygiene practices.

Table 1 – Macronutrient composition of study products (per 100g) for study 1

	Water	OJ	OPF	WO
Glucose (g)	Nil	2.1	2.0	≈2.0
Fructose (g)	Nil	2.6	2.4	≈2.3
Sucrose (g)	Nil	4.3	4.7	≈4.3
Carbohydrates (g)	Nil	10.5	12.7	≈9.0
of which is sugars (g)		9.0	9.1	≈9.0
Protein (g)	Nil	0.63	0.81	≈0.9
Fibre (g)*	Nil	0.26	2.1	≈2.4
Energy (kcal)	Nil	45	55	≈ 36

*Measured by AOAC official method 991.43: Total Dietary Fibre in Foods (Enzymatic-Gravimetric method).

Abbreviations: OJ, orange juice; OPF, orange pomace fiber (added in OJ); WO, whole orange (chopped)

Study 2: There were three treatments: orange-flavoured beverage with 2.5 g of added orange pomace fibre (Low dose, LD-OPF), with 5.5 g of added orange pomace fibre (high dose, HD-OPF), and orange-flavoured beverage without fibre (Control). All products were matched for sugar, protein, and calories (not including calories from fibre), sweetened with Stevia for

palatability, and prepared to provide 255 g (equivalent to 240 ml). The nutrient composition of each study product was listed in Table 2.

The low dose pomace and control were provided in aluminum canisters by PepsiCo Inc. and stored refrigerated no longer than 8 weeks before use. The high dose pomace was prepared on a daily basis at the University of Reading according to good manufacturing practice.

Table 2 – Macronutrient composition of study products (per 100g) for study 2

	Control	LD-OPF	HD-OPF
Glucose (g)	0.56	0.56	0.56
Fructose (g)	0.66	0.66	0.66
Sucrose (g)	1.07	1.07	1.07
Total Sugars (g)	2.29	2.29	2.29
Fibre (g)*	0	0.98	2.17
Protein (g)	0.66	0.66	0.66
Energy (kcal)	11.8	11.8	11.8

* Measured by AOAC official method 991.43: Total Dietary Fibre in Foods (Enzymatic-Gravimetric method). Control, orange-flavoured beverage without fibre; LD-OPF, low dose orange pomace fibre (2.5 g added in orange-flavoured beverage); HD-OPF, high dose orange pomace fibre (5.5 g added in orange-flavoured beverage)

The added OPF for the two studies comprised of edible components of whole orange which are leftover from orange juice processing. The pomace was rich in fibre with 40:60 ratio of soluble to insoluble (this data was provided by PepsiCo and available upon request).

2.3 Measurements of viscosity of OPF

The micronized OPF was added to OJ in order to reach concentrations of 0.98% and 2.12% w/w of dietary fibers. OJ alone had a dietary fiber content of 0.2 % w/w. The blends were then stirred on a magnetic plate for 24h at 4°C to allow complete hydration of the pomace. The samples were then brought to 20°C and their viscosity was measured with a Brookfield DV-II+viscometer (Brookfield, Middleboro MA) in a 1 L beaker containing 750 mL of liquid blend. Measurements were carried out with a SC4-18 spindle at 50 rpm (shear rate of 65 sec-1), in triplicate.

2.4 Study design

The two studies were designed as acute randomized, controlled, double-blind crossover studies. The participants were randomized using a standardized computer program.

Subjects were required to attend the clinic unit four occasions in study 1 and three occasions in study 2 with one week washout between. All subjects from the two studies followed the same procedure. Before each visit the subjects were instructed to minimize changes in their usual lifestyle and to avoid high intensive physical activity and alcohol for 24 hours prior to the study visit. Subjects were given a standard low fat evening meal (<15 g fat) to consume the previous evening and attended the Hugh Sinclair Unit of Human Nutrition the following morning at 8 am after fasting overnight for 12 h (not eating or drinking anything but water). On the visit day, the subjects were asked to complete a 24-hour recall to check their compliance to study protocol. A light breakfast consisted of one slice of white toast (45 g) with butter (10 g) and water (consume within 10 min) was served to provide a stable baseline for hunger ratings. Subjective ratings of hunger and fullness were recorded before, and 15 min after breakfast. One hour after the breakfast, volunteers were asked to consume the intervention drink within 10 min, and further subjective ratings immediately prior to, and every 15 min following the consumption of the test product were collected for a period of two hours. At the first time point after consumption of the test product the subjects were also asked to complete the 9 point hedonic scale where 1 (dislike extremely) and 9 (like extremely). Subjects were asked to refrain from drinking water for 45 minutes prior to consumption of the test product. After consumption of the test product subjects were permitted to drink water which was standardised for each study visit.

2.5 Subjective ratings of appetite

Visual analogue scales (VAS) are commonly used as a simple means of self-reporting subjective ratings of appetite and showed satisfactory reliability and validity (Flint, Raben, Blundell, & Astrup, 2000). Consisting of a 100 mm line, subjects were required to respond to a question by placing a mark on the line that is anchored with an extreme answer at either end of the line, for example, the question “How full are you right now?” would be anchored with “Not at all full” and “Extremely full”, with the minimum value on the left end of the scale.

The questions used in the studies are as follows and were asked in the order shown below:

Q1. How hungry are you right now?

Q2. How strong is your desire to eat right now?

Q3. How much could you eat right now?

Q4. How full are you right now?

Q5. How strong is your desire to consume something sweet right now?

Q6. How strong is your desire to consume something savory right now?

Q7. How thirsty are you right now?

Q8. How comfortable is your stomach/abdomen right now?

In study 1, subjects used paper-based VAS, while in study 2, subjects used a computer-based adaptive VAS (AVAS) software (Neurobehavioral Research Laboratory and Clinic, San Antonio, USA) (Marsh-Richard, Hatzis, Mathias, Venditti, & Dougherty, 2009) to mark the line of the same length as study 1 with an electronic pen.

2.6 Statistical analysis

A sample size of 24 volunteers was sufficient to detect a mean satiety difference of 10 mm with 95 % confidence and 90 % power assuming the standard deviation of mean scores from a 100 mm VAS was 14.

A composite satiety scores (CSS) was used as the primary outcome based on a study conducted by Abou-Samra Rania et al. (Abou-Samra Rania, Lian, Dino, Rajat, & Macé Katherine, 2011) with minor modifications. CSS included VAS ratings of satiety the first 6 questions that was calculated by using the measures for 'fullness' (Q4), 'desire to eat' (Q2, Q5 and Q6),'hunger' (Q1) and 'prospective food consumption' (PFC) (Q3).

CSS = [Fullness + (100-Desire to eat) + (100-Desire to eat something sweet) + (100-Desire to eat something savory) + (100-Hunger) + (100-PFC)]/6

CSS was analyzed by SAS (version 9.2) (SAS Institute Inc., Cary, USA) for product effect using a repeated measures mixed effects model for a crossover design where the independent fixed factors are sequence, period and product, and baseline CSS as a covariate (least squares means, LSM). Evaluation time points were the repeating factor and subjects within sequence was a random factor. The evaluation time points included before consumption of the products (-10min, baseline time point) and immediately after the products (0 min) and then every 15 min till 2 hours (15, 30, 45, 60, 75, 90, 105, 120 mins). Same method as CSS was used to analyse the scores of each of the eight questions. Liking scores and time taken to consume the products were analysed by one way repeated measures ANOVA. Bonferroni correction was used for multiple pairwise comparisons. All data were presented by LSMs ± SE.

3. Results

229 *3.1 Viscosity of OPF*

230 Addition of OPF to the OJ increased the viscosity of the juice in a dose dependent manner as
231 shown in Table 3.

232 Table 3. Brookfield viscosity of blends of OJ and dietary fiber at concentrations of 0.2, 0.98
233 and 2.12 % (w/w).

	Brookfiled viscosity (cP)
OJ (0.2 % dietary fibers)	33 ± 3
OPF + OJ (0.98 % dietary fibers)	790 ± 12
OPF + OJ (2.12 % dietary fibers)	8000 ± 970

234 Results are given as mean ± SD of triplicate measurements.

235 Abbreviations: OJ, orange juice; OPF, orange pomace fiber

236 *3.2 Subject characteristics*

237 Study 1. Seven females and 17 males completed the study with a mean age of 42 ± 3.3
238 years for all subjects and a mean BMI of 23.4 ± 0.43 kg/m^2. All of the test products were well
239 tolerated by subjects and no adverse effects were observed.

240 Study 2. Fourteen females and 16 males completed the study with a mean age of 31.4 ± 2.0
241 years and BMI of 23.8 ± 0.44 kg/m^2. All of the test products were well tolerated by subjects
242 and no adverse effects were observed.

243 *3.3 Short-term satiating effect over 2 hours of Study 1*

244 The satiating effect of four products including OPF, WO, OJ and water was investigated in
245 study 1.

246 Figure 1 showed the LSMs of CSSs among the four treatments. There was a steady
247 decrease in CSSs following the intake of all products during the study hours; however the
248 OPF consumption maintained the highest level of satiation until 120 min with proximity
249 effect of WO, while the OJ satiety level was between OPF/WO and water. There was
250 significant treatment difference of OPF, WO and OJ consumption on CSS compared with
251 water. OPF and WO showed significantly higher satiating effects compared with OJ, while
252 there was no significant difference between them.

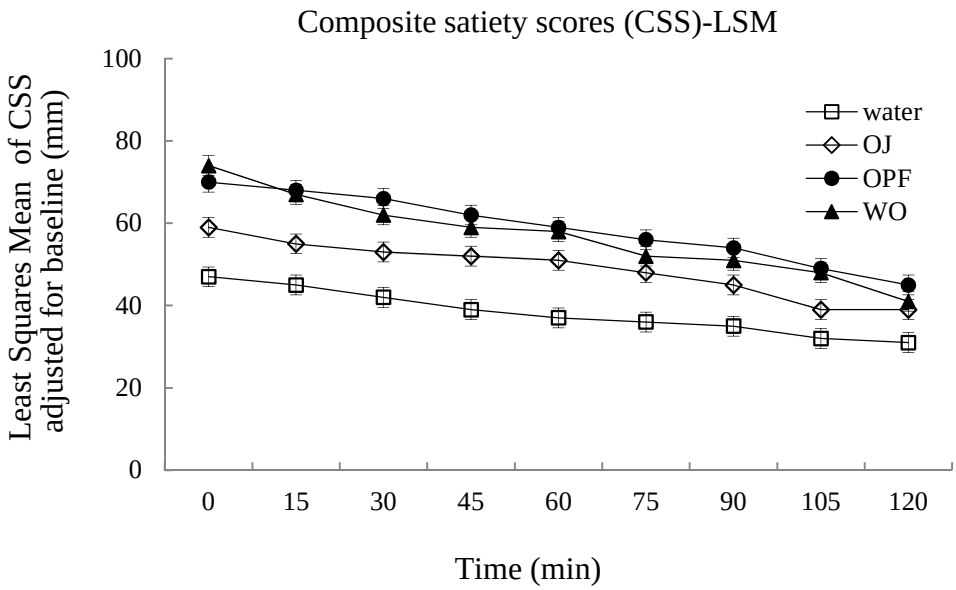

Figure 1. Short term satiating effect in CSS after consumption of OPF, WO, OJ and water (study 1) up to 120 min.

The data were presented by LSM ± SE. CSS, composite satiety scores; LSM, least squares means; OJ, Orange juice; OPF, orange pomace fibre (5.5 g added in OJ) ; WO, peeled chopped whole orange. OPF (or WO or OJ) vs water, P<0.0001; OPF (or WO) vs OJ, P<0.0001. No significant difference between OPF and WO by using a repeated measures mixed effects model adjusted by baseline.

Figure 2 illustrated the LSMs of individual questions. The 'hunger' scores progressively increased across all treatments throughout the remainder of the study up to 120 min (Figure 2). However, OPF and WO consumption was associated with the lowest hunger score, and water the highest with the effect of OJ in between. Multiple pairwise comparisons using Bonferroni correction showed significant differences between OPF (or WO) and OJ, OPF (or WO) and water, and OJ and water. OPF and WO did not differ significantly throughout the study period (P=0.49). 'Desire to eat' followed a very similar pattern to the hunger data with OPF and WO resulting in significantly less 'desire to eat' than both OJ and water consumption, and OJ also decreasing the 'desire to eat' significantly compared with water. There was no significant difference between OPF and WO (P=0.29). Again, responses to 'feeling of how much you could eat right now' followed a similar pattern to 'hunger' and 'desire to eat' questions, as shown in figure 2. OPF and WO resulted in much less feeling of 'how much to eat' compared with OJ and Water. There was also a significant difference between OJ and Water, but no difference was observed between OPF and WO. As expected, feelings of 'fullness' followed an inverted pattern to the previous questions on hunger. OPF

and WO kept the subjects significantly fuller over the time period compared to OJ or the water. OJ intake also induced significantly fuller feeling than Water. There was no difference between OPF and WO.

Questions on the 'desire to consume something sweet' and 'savory' showed similar results to the questions on 'hunger', 'desire to eat', 'how much to eat' except that OPF intake resulted in less 'desire to eat something sweet' than WO (P=0.0133) (Figure 2).

There was no significant difference between treatments either regarding 'feeling thirsty' or responses to 'abdominal comfort' which remained fairly consistent for each treatment throughout the study (data not shown).

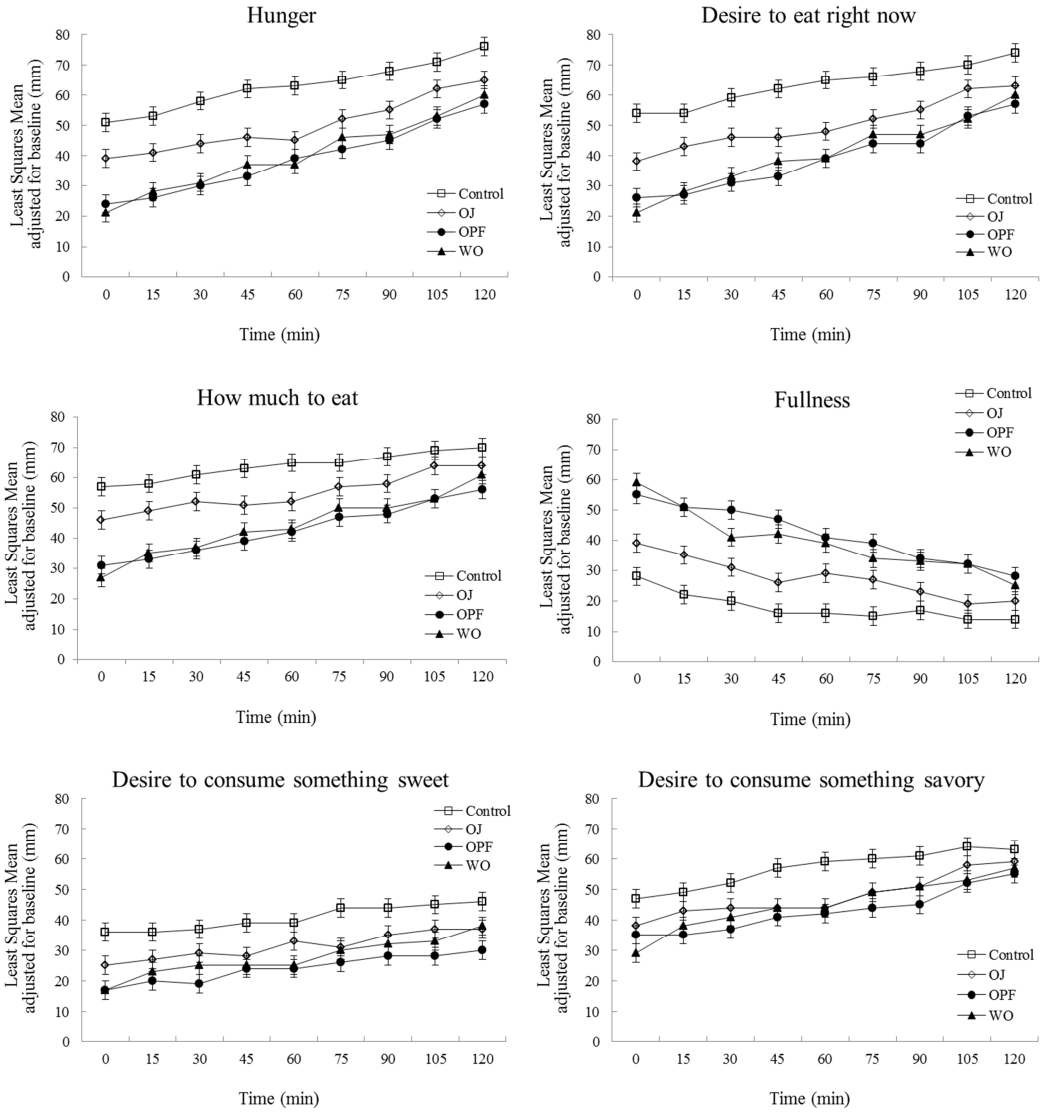

Figure 2. Short term satiating effect regarding individual questions after consumption of OPF, WO, OJ and water (study 1) up to 120 min.

The data were presented by LSM ± SE. LSM, least squares means; OJ, Orange juice; OPF, orange pomace fibre (5.5 g added in OJ); WO, whole orange, peeled and chopped. For 'Hunger', 'Desire to eat right now', 'How much to eat', 'Fullness', 'Desire to consume something sweet', 'Desire to consume something savory', OPF (or WO) vs OJ (or water), P<0.0001; OJ vs water, P<0.0001; For 'Desire to consume something sweet', OPF vs WO, P=0.0133 by using a repeated measures mixed effects model adjusted by baseline.

Participants were asked to rate their liking of the product on a 9-point hedonic liking scale. On average, WO and OJ were the most liked by participants with scores of 7.9 ± 0.2 and 7.8 ± 0.1. The OPF and Water were the least liked with scores of 5.9 ± 0.4 and 5.2 ± 0.2. However, the distribution of scores demonstrated that 67 % of the liking scores for OPF were above 5, while this was only 17 % for water. WO and OPF took the longest time to consume on average 6.4 and 6.3 min respectively than OJ and Water (averagely 4.4 min and 3.9 min). This was most likely caused by the higher levels of fibre found in these treatments.

3.4 Short-term satiating effect over 2 hours of Study 2

The satiating effect of three products including HD-OPF, LD-OPF and Control was evaluated in study 2. Figure 3 demonstrated that high and low dose OPF were more satiating than control by illustration of CSSs, but differences were only significant with the high dose. HD-OPF was reported to be significantly more satiating than LD-OPF.

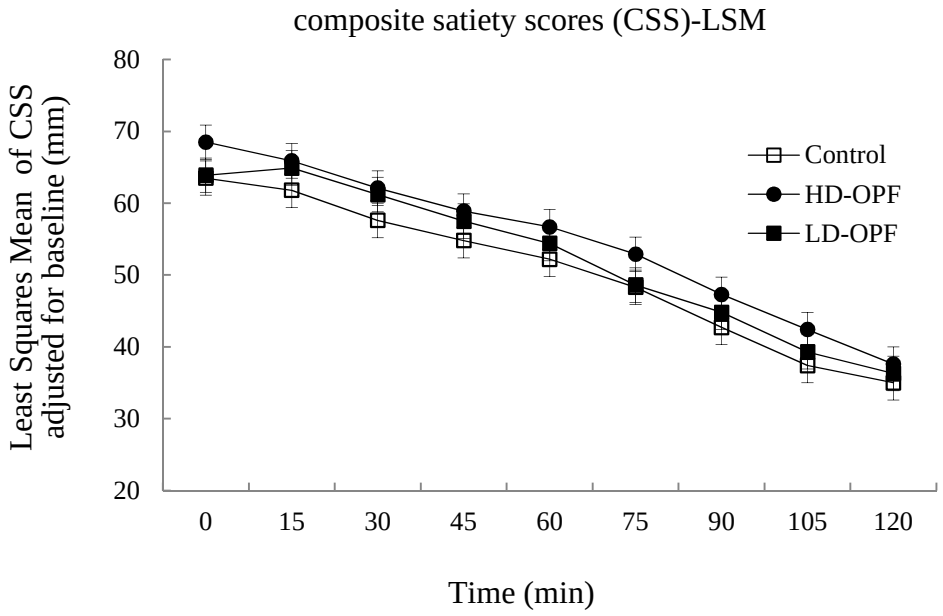

Figure 3. Short term satiating effect in individual questions after consumption of HD-OPF, LD-OPF and control (study 2) up to 120 min.

The data are shown as LSM ± SE. CSS, composite satiety scores; LSM, least squares means; LD-OPF, low dose of 2.5 g orange pomace fibre added in orange-flavoured beverage; HD-OPF, high dose of 5.5 g orange pomace fibre added in orange-flavoured beverage; Control, orange-flavoured beverage without fibre. HD-OPF vs Control, P<0.0001, HD-OPF vs LD-OPF P=0.043 by using a repeated measures mixed effects model adjusted by baseline.

Figure 4 illustrated the LSMs of individual questions regarding satiety scores with similar pattern to study 1. The high dose consistently showed significantly less 'hunger' than control and low dose throughout the study period (Figure 4). Low dose pomace induced less 'hunger' than control during the first hour of the study period, but this did not reach significantce (Figure 4). Both high and low dose resulted in significant less 'desire to eat' than the control with no difference between high and low dose (Figure 4). High dose significantly suppressed the feeling of 'how much they could eat' through the study period compared to either control or low dose, but low dose did not show any effect compared to control (Figure 4). The subjects were significantly fuller after consuming the high compared with the low dose, but marginally significant compared to control (P=0.0588). No effect of low dose was observed regarding 'fullness' (Figure 4). However, both high and low dose induced a significant reduction in 'desire to consume something sweet' compared to control without difference between them (Figure 4). There was no effect of either high or low dose on the feeling of 'desire to comsume something savory' compared to the control (Figure 4), or on the feeling of 'thirst' and 'abdominal comfort' (data not shown).

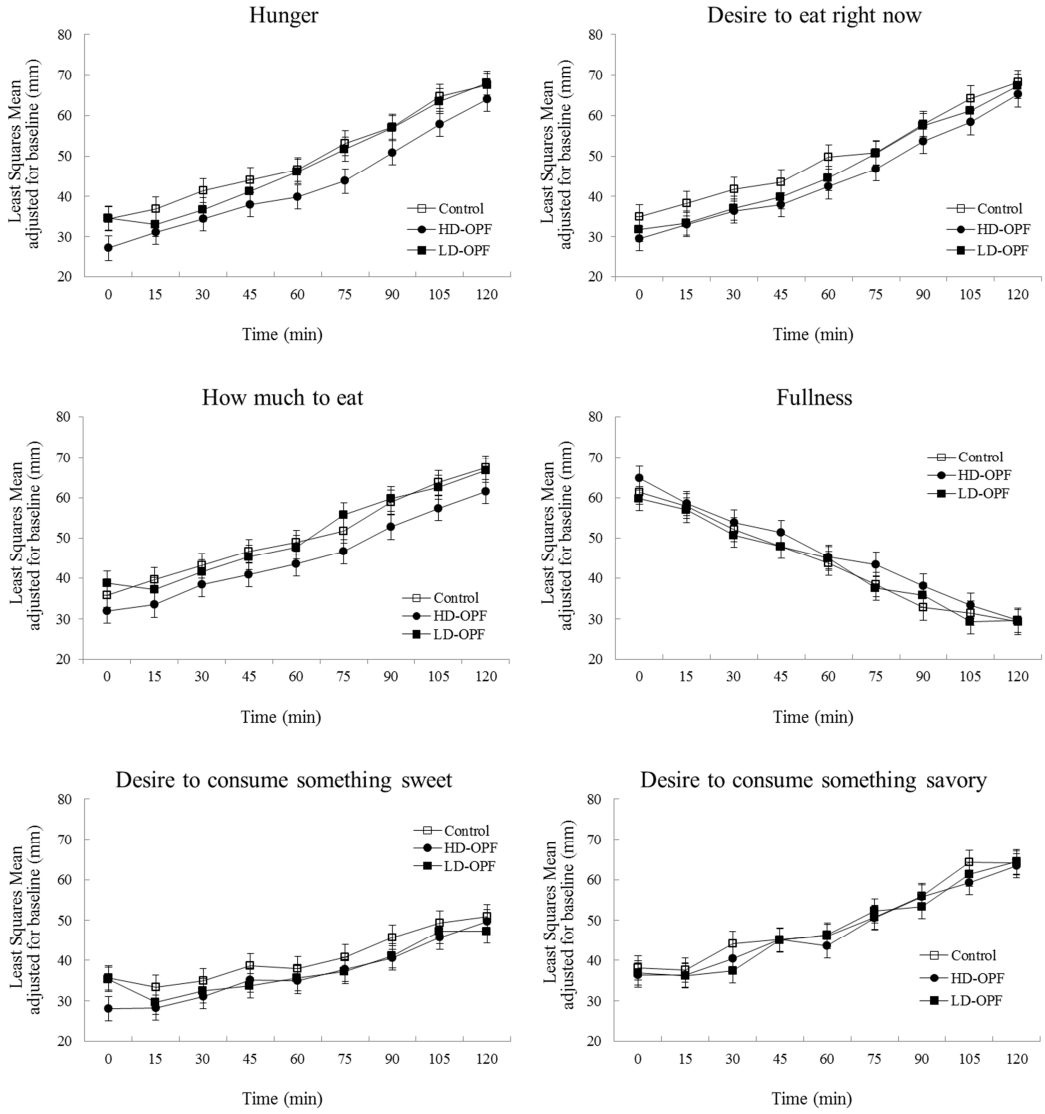

Figure 4. Short term satiating effect regarding individual questions after consumption of HD-OPF, LD-OPF and Control (study 2) up to 120 min.

The data are shown as LSM ± SE. LD-OPF, low dose of 2.5 g orange pomace fibre added in orange-flavoured beverage; HD-OPF, high dose of 5.5 g orange pomace fibre added in orange-flavoured beverage; Control, orange-flavoured beverage without fibre. 'Hunger', HD-OPF vs LD-OPF, P=0.0005; HD-OPF vs control, P<0.0001. 'Desire to eat right now', HD-OPF vs Control, P<0.0001; LD-OPF vs Control, P=0.038. 'How much to eat', HD-OPF vs LD-OPF or Control, P<0.0001. 'Fullness', HD-OPF vs LD-OPF P=0.049. 'Desire to consume something sweet', HD-OPF vs Control, P=0.0002; LD-OPF vs Control, P=0.0089 by using a repeated measures mixed effects model adjusted by baseline.

The 9-point hedonic liking scale showed that the 'favorite' was the low dose (mean score of 6.3 out of 9). High dose was the least liked (mean score of 4 out of 9) and was significantly different from both low dose and the control (P<0.01 for both). For the high dose, a 'liking'

score of 30 % of subjects was above 5, while for low dose this was 83 %, and 70 % for control.

As expected the high dose took longer to consume (5.2 min in average) than both control (2.7 min in average, P<0.0001) and low dose (3.3 min in average, P=0.003). There was no difference in either liking scores or time taken to consume between low dose and the control.

4. Discussion

In these two short-term studies, all products were matched for macronutrient and energy composition except for water in study 1, differing only in their fibre content. The studies demonstrated that addition of OPF to OJ was as effective at increasing subjective satiety ratings illustrated by the composite satiety scores as WO (peeled and chopped) consumption compared with OJ (study 1); and there was a trend of dose-dependent effect of OPF in an orange-flavoured beverage on satiety compared with the control containing same calories but no fibre.

It is likely that the addition of OPF to OJ or beverage caused the satiating effect observed. The added OPF was dietary fibre leftover from the production of OJ, which was subjected to particle size reduction. Previous investigations suggested that the viscosity-forming capacity of water-soluble fibres such as guar gum and β-glucan, is crucial for their impact on satiety (Rebello et al., 2014; Slavin & Green, 2007). Our experimental viscosity measurements showed that addition of OPF in OJ greatly increased the viscosity of the juice, in particular at higher dose of 2.12 %. Viscous dietary fibres induce thickening when mixed with liquids and absorb large quantities of water. This can increase stomach distension, reduce rates of gastric emptying which may trigger afferent vagal signals of fullness, promoting satiety through mechanical mechanisms (Kristensen & Jensen, 2011; Zhu, Hsu, & Hollis, 2013). This could explain why the impact of the test meals was so rapid in onset. Since the satiating effect of OPF and WO was retained throughout the 2 hours of study period, modulation of gut hormone production, such as ghrelin, glucagon-like peptide 1 (GLP-1), and peptide YY (PYY) may be involved in the regulation of satiety (Karhunen et al., 2010; Ye, Arumugam, Haugabrooks, Williamson, & Hendrich, 2015). However, some studies with dietary fibres did not affect perceived appetite or subsequent energy intake despite differences in satiety hormone signalling in overweight females (Lafond et al., 2015) or in healthy young adults

(Karhunen et al., 2010). In the current research, this relationship between satiety rankings and satiety hormones was not tested, however it warrants future studies.

In addition, evidence suggests that low-glycemic foods or meals may promote higher satiety than high-glycemic foods or meals and that glycemic responses of foods modulate satiety (Guérin-Deremaux et al., 2011) Viscosity formed when the fibre is dissolved in water (liquid), may entrap nutrients in the viscous matrix resulting in slow release of nutrients such as glucose into the blood, affecting appetite-regulating peptides (Kristensen & Jensen, 2011). A few studies found that intake of viscous fibre increased short-term satiety by using VAS scores and reduced postprandial glucose levels (Konings, Schoffelen, Stegen, & Blaak, 2014; Solah et al., 2014). However, the relationship between postprandial glucose/insulin responses and satiety regulation is still not clear.

In the current two studies, OPF (5.5 g fibre in OJ in study 1 or orange-flavored beverage in study 2) and WO took significantly longer to consume compared with OJ or 2.5 g fibre beverage and controls because of their thickness, which may have suppressed appetite ratings further. Previous studies have suggested that eating slower increased fullness and decreased hunger ratings and reduced energy intake during ad libitum meals in in the normal weight subject (Shah et al., 2014) and overweight and obese participants with T2DM (Angelopoulos et al., 2014). Shal et al.'s study asked subjects to complete consumption of a mixed meal of vegetable pasta as fast as possible at one occasion or as slow as volunteer wanted at another occasion, but there was no indication of the exact time to consume meals for those two sessions. In Angelopouos et al.'s study, volunteers were provided a 300 mL ice-cream in two different sessions at a speed of 5 or 30 min to consume. However, it is unknown whether the actual absolute amount of time difference between treatments at the current student presents a biologically plausible reason for altered subjective ratings.

Low dose pomace induced less satiety than high dose, but showed more satiating than Control by suppression of the desire to eat in study 2. However low dose was the favorite product among the three tested, while 5.5 g orange pomace either added to OJ or orange-flavored beverage was least liked because of the thickness. In spite of a scarcity of studies, palatability, liking or pleasantness for the sensory aspects of food are increasingly measured in dietary intervention studies for dietary acceptance. This is central to the development, maintenance and change of dietary patterns (Eertmans, Baeyens, & Van, 2001; Solah et al.,

2014). Therefore, the sensory aspects of products need to be determined and optimized in commercial products.

In conclusion, addition of 5.5 g OPF to either OJ or orange-flavoured beverage increased short-term satiety significantly and more effectively than either low dose pomace (2.5 g OPF) or Control, and the effect is comparable to WO. Low dose of orange pomace also promoted satiety compared to Control. Further studies are needed to investigate the effect of a sustained effect on appetite ratings and on body weight by continuous consumption of orange pomace.

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