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Effect of Ginger-enriched Pasta on Acceptability and Satiety

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ABSTRACT:

Ginger is attributed with beneficial bioactivities. The aims of this study were to analyse the bioactive compounds in commercial ginger powders, and assess acceptability and satiety responses to ginger-enriched wheat pasta in healthy human volunteers. Powders were extracted with methanol and extracts analysed by HPLC-UV/LC-MS. Results indicated that 6-, 8-, 10-gingerol, 10-shogaol were the principal bioactive components. The liking of pasta enriched with 1%, 3% and 5% (w/w) ginger powder was evaluated for four sensory attributes and overall liking using a 9-point hedonic scale. All pasta products were generally liked to a similar extent to the control, with the exception of the liking for colour of the pasta with 5% ginger ($p<0.02$). Ten healthy subjects consumed two samples of equal weight: control and ginger enriched pasta (3%), on two occasions. Subjective feelings of satiety were assessed pre-consumption, immediately after and for two hours post-consumption using a 7-point intensity scale analyzed using Rasch modelling. Results show that the ginger pasta sample had a similar satiety response compared to the control pasta up to two hours after consumption. In conclusion, ginger-enriched pasta is generally accepted by consumers, but not does not lead to higher satiety compared to the control.

Practical Application:

- Gingerols are the main bioactive components in commercial ginger powders.
- Ginger-enriched pasta is well accepted by consumers from a sensory point of view.
- Ginger-enriched pasta does not lead to higher satiety compared to control pasta.

Keywords.

46 Ginger; Gingerol; Shogaol, Pasta, Sensory, Satiety

47

1 Introduction

Ginger, the rhizome of the perennial plant *Zingiber officinale* Roscoe, is one of the most widely used spices around the world (Raquel Sehn, De Cássia Nogueira, & Steel, 2015). The popularity of ginger is due to its distinctive pungency and aroma (Mancini et al., 2017). Ginger powder is the most important form in international trade, used as an ingredient in food processing (Salmon et al., 2012). Apart from being used as a spice, ginger has a long history in traditional medicine for thousands of years in China and India (Ok & Jeong, 2012; Salmon et al., 2012). It is traditionally used to treat gastrointestinal and rheumatic disorders (Afzal, Al-Hadidi, Menon, Pesek, & Dhami, 2001). There is also evidence that ginger has anti-inflammatory, anti-oxidative and anti-obesity activities and these effects are attributed to the bioactive components such as gingerols, flavonoids and phenols (Nicoll & Henein, 2009; Rahmani, Shabrmi, & Aly, 2014).

Gingerols and shogaols are two main bioactive compounds in ginger (Figure 1). Gingerols are responsible for the pungency of ginger. They exist as 6, 8-, and 10-gingerols with different length of unbranched alkyl chains. Gingerols have been shown to elicit various physiological effects (Semwal, Semwal, Combrinck, & Viljoen, 2015). Among gingerols, 6-gingerol (1-4'-hydroxy-3'-methyoxyphenyl-5-hydroxy-3-decanone) is the most abundant constituent in fresh ginger (Figure 1A). However, it decreases during thermal processing and post-harvest storage (Swapna Sonale & Kadimi, 2014). Regarding shogaols, their structure is similar to gingerol but with a 4,5-double bond, resulting from the elimination of 5-hydroxy group (Figure 1B) (Dugasani et al., 2010; Swapna Sonale & Kadimi, 2014). Present in low concentrations in fresh ginger, shogaol content will increase when gingerols are exposed to heat, acid or other conditions which allow the alkene to form (Astrup et al., 2010; Bhattarai, Tran, & Duke, 2001). It is reported that shogaols are even

more pungent than gingerols and 6-shogaol has more potent pharmacological effects than 6-gingerol (Dugasani et al., 2010; Pan et al., 2008).

The incidence of obesity has increased steadily worldwide over recent decades. It is a major risk factor for many diseases, including diabetes, cardiovascular disease and certain types of cancer (Heymsfield & Wadden, 2017). One possible strategy to achieve weight management is through functional bioactive-enriched foods (Bordoni, Boesch, Malpuech-Brugère, Orfila, & Tomás-Cobos, 2019; Sunkara & Verghese, 2014) and satiety-inducing foods in particular (Munekata et al., 2021). The concept of functional foods includes “food or food ingredients that exert a beneficial effect on health and/or reduce the risk of chronic disease beyond basic nutritional functions” (Milner, 2000). There has been increased interest in functional foods due to consumers’ increased consciousness of the role of healthy eating in disease prevention (Charalampopoulos, Wang, Pandiella, & Webb, 2002). Enriching staple foods with bioactive functional ingredients that promote satiety could be an effective strategy to help in weight maintenance with a sustainable effect in the long term.

Evidence has shown to suggest that the bioactive compounds found in ginger (gingerol and shogaol) could affect energy balance, leading to effective weight management (Astrup et al., 2010). Several animal studies have reported that supplementing mice fed high fat-diet with different forms of ginger extracts significantly reduced their food intake, compared to control mice, resulting in weight loss (Kadnur & Goyal, 2005; Nammi, Sreemantula, & Roufogalis, 2009; Zuberi & Browning, 2009). Ginger has also been shown to reverse the delay in gastric emptying in rats leading to the acceleration of the gastrointestinal transit time (Gupta & Sharma, 2001; Sharma & Gupta, 1998). Furthermore, perfusion of rat hind-limbs with ginger extracts increased

oxygen consumption and thermogenesis activity (Eldershaw, Colquhoun, Dora, Peng, & Clark, 1992). However, evidence from human studies is inconsistent. One study has found that the consumption of ginger capsules (total of 1.2 g) increased gastric emptying and motility (Hu, 2011). In contrast, other studies failed to confirm such effects using 1 g doses (Henry & Piggott, 1987). It has been suggested that doses greater than 1-1.2 g of ginger may be necessary to demonstrate noticeable effects (Mattes, 2005). Findings from a pilot study have revealed enhanced thermogenesis, reduced feelings of hunger and increased satiety following the ingestion of a hot ginger beverage (2 g) (Mansour et al., 2012). However, this satiating effect was not observed in other studies where ginger was consumed in capsule form or as a meal component (Hu, 2011; Reinbach, Martinussen, & Møller, 2010). More recent studies have successfully demonstrated a 2% decrease in weight and BMI following the administration of ginger capsules (2 g/day) for 8 to 12 weeks among overweight and obese women (Ebrahimzadeh Attari, Ostadrahimi, Asghari Jafarabadi, Mehralizadeh, & Mahluji, 2016; Taghizadeh et al., 2017). Pasta is a traditional staple food product that is popular because of its ease of cooking, storage, and nutritional value as a low-glycemic index food (Björck, Liljeberg, & Östman, 2000). We considered that pasta would be an ideal vehicle for ginger enrichment because of its popularity (Laureati, Conte, Padalino, Del Nobile, & Pagliarini, 2016). Bioactive enriched staple foods have been shown to be promising for delivering bioactives to Western populations (Bub et al., 2019; Gani, Fearnley, Ho, & Orfila, 2018). The acceptance and sensory experiences such as appearance, smell, taste and texture of food products are believed to play crucial key in improving satiety and controlling food intake (McCrickerd & Forde, 2016).

The current study aims to identify and quantify the bioactive components in commercial ginger powders to investigate the effect of ginger enrichment (1%, 3% and 5% w/w) on consumer acceptability, sensory and satiety responses. It is hypothesized that 6-gingerol and 10-shogaol are the principle bioactive components in ginger powders and the consumption of ginger-enriched pasta increases satiety, compared to control pasta.

2 Materials and Methods

2.1 Materials and reagents

Ginger powders (A-E)–and ingredients for pasta making were purchased from local stores in Leeds, UK. All we labelled as being 100% ginger, with no fillers. For quantification, 6-gingerol standard (CAS: 23513-14-6) with purity higher than 98% was purchased from Insight Biotechnology. The other chemicals and solvents for chromatography analysis were of HPLC-grade.

2.2 Chromatography analysis

2.2.1 Sample preparation

Ginger powder (0.5 g ± 0.1 mg) was weighed and placed into a 25-mL volumetric flask. Methanol (20 mL) was added and the mixture sonicated for 60 min at room temperature (22℃). After sonicating, volume was re-adjusted by adding methanol and the supernatant filtered through 0.45 µm nylon filters and then placed into HPLC vial with caps. Compounds were identified by HPLC-DAD using the relative retention time, and confirmed by MS (table 1).

2.2.2 Chromatographic conditions

Samples and standards were analyzed by HPLC-DAD-MS (Shimadzu Prominence system with a binary pump (LC-30AD), autosampler (SIL-30AC), column oven (CTO-20AC), PDA detector (SPD-M20A) and controller (CBM-20A). MS detector is a single quadrupole mass spectrometer (Shimadzu LCMS-2020), using electrospray ionization. The method was run in both positive and negative mode scans (200-400 m/z), as well as positive and negative SIM mode. m/s values monitored were (-ve/+ve) 265/267, 293/295, 321/323, 377/379, 275/277, 303/305, 331/333 and 359/361. Samples (20 µL) were injected using the autosampler into a YMC-Pack Pro C18 column (4.6×250 nm, 5 µm, 120 A). The column temperature was set to 30 ℃ and the flow rate was 1.0 mL/min. The injection volume was 20 µL. Water (A) and Acetonitrile (B) were used as eluents and the gradient elution had the following profile: 0-8 min, 45% B; 8-15 min, 50% B; 15-40 min, 55% B; 40-45 min, 90% B; 45-55 min, 45% B.

2.3 Ginger-enriched pasta preparation

Ginger-enriched pasta was made using commercial pasta flour (strong wheat flour labelled 00 according to industry standards), distilled water and ginger powder (sample C). This sample was the most polular and readily on the UK market, and was therefore chosen for enrichment. Control pasta was made using 100% of the same pasta flour (w/w) and 50% of water (w/w). Ginger was incorporated into ginger-enriched formulations by substituting the flour in the following proportions (w/w): 1%, 3%, and 5%. The ingredients were mixed and kneaded using an electric mixer (KMC515, Kenwood Ltd., England). The mixture was then extruded into 1 mm thickness sheets using a manual pasta roller, followed by cutting the sheets into tagliatelle strips of

approximately 7 mm width and 20 cm length using cutting rolls. Negligible amounts of flour were added during sheeting and rolling to prevent the dough from sticking.

The best drying result was achieved through a two-step process. Pasta strands were hung on a pasta drying rack at room temperature for about 40 min as a preliminary step to facilitate forming pasta strands into nests, ensuring they do not stick together. The pasta nests were placed on a cooling rack and left to air-dry at room temperature for 24 h. Dried samples were packed in polyethylene bags and stored at room temperature until needed (maximum of 5 days). The resultant dried product was then tested for moisture content using a moisture analyzer (Mettler Toledo, HB43-S), in which dried samples achieved the required moisture content of 11% for safe consumption.

2.5 Cooking procedure

Optimum cooking time (OCT) to achieve complete gelatinization of starch was determined as 13 min, following the AACC 66-50 standards, defined as when the inner white core of pasta disappears after squeezing the pasta strands between 2 glass plates (Li & Vasanthan, 2003). 100 g of dried pasta was cooked in 1 L of boiling water, to which 8 g of salt was added. After cooking pasta for its OCT, it was then rinsed with cold water, drained for 5 min and seasoned with 10 g of extra-virgin olive oil (Laureati, Conte, Padalino, Del Nobile, & Pagliarini, 2016). Cooking losses was determined by evaporating the combined cooking water and rinse water at 110°C till constant weight was obtained and cooled in a desiccator.

$$cooking\ loss\ (\%) = \frac{weight\ of\ solid\ residue\ after\ drying}{weight\ of\ uncooked\ noodles}\ x\ 100$$

2.6 Sensory evaluation trial

The sensory evaluation and satiety trials were approved by the University of Leeds Ethics Committee (reference MEEC 15-003). For the sensory trials, we expected a difference of 0.5 to be significant for one-power Anova at 95% confidence level, and standard power of 80%, comparison of 4 samples. A sample size of n = 12 was calculated using R statistical package (https://CRAN.R-project.org/package=pwr). Thirty-two untrained panelists (27 females and 5 males) between the ages of 18 and 34 were recruited among students and staff of the School of Food Science and Nutrition at the University of Leeds. The sensory evaluation was performed in a single session lasting 10 to 15 min. After reading a participant information sheet, panelists first signed an informed consent form that included a sufficient description of the trial. They were also asked to complete a short questionnaire that included some demographic questions (gender and age), the frequency of their pasta consumption, and their overall liking of ginger.

To avoid any change in the sensory properties of the samples, they were cooked one at a time, each type of pasta experiencing the same time and temperature history prior to the test. The panelists received four samples: three ginger-enriched pasta samples and the control (Figure 2). Samples were served one at a time in a randomized order, in small transparent plastic pots coded with a three-digit randomized code, each containing 30 g of cooked pasta. A randomized experimental design for the sample presentation order was created with DesignExpress V.1.7 (Qi Statistic and Product Perceptions, Berkshire, UK). Data was collected with Compusense® Five (Compusense Inc., Guelph, ON, Canada). Panelists were asked to evaluate each pasta sample for five sensory attributes: liking of color, liking of smell, liking of texture, liking of taste and overall liking. Each attribute was rated on a 9-point hedonic scale (1= Dislike extremely, 9= Like extremely). Drinking water was provided for palate cleansing between samples.

198 **2.6 Satiety trial**

199 Ten healthy panelists were recruited for the satiety trial (9 females and 1 male). A within-subject
200 design with two conditions was used in this study. With n = 10, an effect size of 1.2 would have
201 been needed to find a significant difference. The effect size is based on the value for the F statistic
202 in the repeated measures ANOVA using the R function for statistical power analysis
203 (https://CRAN.R-project.org/package=WebPower). Each panelist completed the study on two
204 separate days, receiving either ginger-enriched pasta or control pasta on each day. Half of them
205 received the first sample in the first session, and another half received the second sample first.
206 All satiety sessions took place in laboratory conditions and were performed in the morning
207 between 9:30 and 11:00. The day and time schedules were arranged based on each panelist's
208 availability. Panelists were asked to refrain from eating or drinking anything on the morning of
209 the trial and for two hours post-consumption, although they were allowed to consume water up
210 to 1 hour prior to the testing.

211 On the first day of the trial, panelists signed an informed consent form and completed a short
212 questionnaire containing general demographics and questions about whether they had eaten or
213 drunk anything that morning to ensure the instructions were followed. Panelists were required
214 to rate five satiety questionnaires at ten-time intervals; before consumption, immediately after
215 consumption and at 15, 30, 45, 60, 75, 90, 105 and 120 min after consuming the meal. The satiety
216 questionnaires (feelings of hunger, fullness, current desire to eat more food, current desire to
217 eat the next meal and current willingness to eat) were rated using a 7-point intensity scale with
218 equally spaced category labels worded as: None, Barely, Slightly, Moderately, Very, Extremely
219 and Strongest Imaginable. The scoring was standardized among all questions (1= Strongest

imaginable, 7= None), except for the fullness question as this goes in the opposite direction and for analysis purposes. These ratings will be referred to as ratings of satiety.

Panelists received about 65 g (dry basis) of cooked pasta in transparent plastic pots, following the cooking procedure mentioned earlier. They were asked to consume the portions entirely within 10 min. Each portion of the enriched pasta contained approximately 2 g of dried ginger (2 g of ginger in 65 g of pasta is equivalent to 3% ginger pasta, we did not measure final ginger content in the final cooked product). This dose was chosen as it had previously been identified as an effective dose to reduce energy intake without significant gastrointestinal side effects (Mansour et al., 2012). Panelists were required to drink 200 ml of water after completing the 'immediately after' consumption satiety ratings to eliminate any satiating effect of water. Panelists were then asked to take copies of the questionnaire with them and complete one every 15 min for 2 hours. A reminder had been sent to their registered emails to remind them to rate the satiety questionnaires. The completed answer booklets were collected at the end of the same trial day that took place.

2.6 Statistical and Rasch analyses

According to the molecular mass, the bioactive components were identified by LC-MS. For the quantification, the content of each compound was calculated based on peak area, using the 6-gingerol standard curve. A parametric ANOVA with pairwise comparison using a Tukey HSD test was undertaken to compare 6-gingerol, 8-gingerol and 10-gingerol contents, while non-parametric test with pairwise comparisons using a Dunn test was done to compare 6-shogaol and 10-shogaol in ginger samples.

241 All raw data obtained from sensory and satiety tests were assigned numerical scores prior to data
242 analysis. Comparisons regarding hedonic sensory analysis ratings between corresponding pasta
243 products were analyzed using the Friedman 2-way ANOVA method, followed by multiple pairwise
244 comparisons using the method of Nemenyi (1963). A repeated measures Rasch analysis
245 (Mallinson, 2011)(Ho, 2019) was conducted using WINSTEPS software (version 3.92.1) to
246 estimate a single measurement of satiety based on the five ratings of satiety questions. Reliability
247 statistics were also calculated to improve data fitness to the mathematical model. In addition, t-
248 tests were calculated to compare the two samples. 95% confidence level was used in all statistical
249 analyses.

250 # 3 Results and Discussion

251 ## 3.1 Identification and quantification of the key components of ginger powder

252 Examples of chromatograms arising from HPLC-DAD analysis of commercial ginger samples are
253 shown in Figure 3. Five peaks were identified and selected for MS analysis. Their retention time
254 and putative identification is shown in Table 1. Peak 1 co-eluted with 6-gingerol. In SCAN (E-)
255 TIC mode, peaks 2, 3, 4 had adduct ion at mass-to-charge (m/z) of 321, 331 and 349 and were
256 identified as 8-gingerol, 10-shogaol and 10-gingerol respectively (Salmon et al., 2012). MS
257 negative mode was more sensitive than positive mode in detecting these compounds under the
258 condition used for the analysis. There was a small peak (#5) between peaks 2 and 3 in sample E
259 (Figure 3B). According to the molecular mass of this peak (m/z 276), peak #5 can be defined as
260 6-shogaol. However, this peak was too small to be detected in ginger sample A (Figure 3A). The
261 main bioactive components in ginger powders were 6-, 8-, and 10-gingerol 10-shogaol.
262 Different commercial samples have different profiles of their compositions. This result was

supported by previous work, which demonstrated that gingerols and shogaols were the major bioactive components (Baliga et al., 2011), following the descending order of 6-gingerol, 10-shogaol, 10-gingerol, 8-gingerol and 6-shogaol (Marx, Isenring, & Lohning, 2017; Yeh et al., 2014).

In order to quantify the compounds in ginger powder, a regression analysis of the 6-gingerol standard curve was conducted. The standard curve of 6-gingerol was linear between 0.02 to 0.2mg/mL with the correlation coefficient higher than 0.998 (data not shown). The contents of 6-gingerol, 8-gingerol ,10-gingerol, 6-shogaol and 10-shogoal contents in gingerol equivalents (GE) are presented in Table 2. For all samples, 6-gingerol was the most abundant component (average for all samples 1.00 ± 0.36%) and 10-shogaol was the second most abundant component (0.36 ± 0.10% GE). This was in accordance to previous findings (Baliga et al., 2011; Swapna Sonale & Kadimi, 2014). Besides, the percentage of 8-gingerol and 10-gingerol were similar (0.26% ± 0.04% and 0.26% ± 0.08% GE, respectively) while the mean content of 6-shogaol was the lowest in all samples (0.11% ± 0.10% GE).

The content of 6-gingerol and 8-gingerol varied significantly among samples. Sample B had the highest content of 6-gingerol, which was around triple the content for that in sample E. For 8-gingerol, sample D contained a significantly higher amount than others. On the contrary, no significant difference was detected in 10-gingerol among these five samples. The results indicated no differences between samples C, D and E for 6-shogaol, and not detected in samples A and B. The content for 10-shogaol in samples A and B were significantly different. The relatively lower percentage of 6-shogaol revealed that the conversion from 6-gingerol to 6-shogaol was insignificant during processing or storage (Swapna Sonale & Kadimi, 2014).

Although the contents followed a similar pattern to previous works, the average level in this study was slightly higher (Marx et al., 2017; Schwertner & Rios, 2007). This may be owing to the genetic differences of samples, such as different regions and physiological responses to the environment like climate and soil characteristics (Henry & Piggott, 1987)..

3.2 Sensory testing

Results comparing the sensory attributes of the four pasta products are summarised in Table 3. The sensory analysis revealed that all pasta products were generally liked to a similar extent. Notably, the liking of the color of the 5% ginger pasta was lower at a statistically significant level compared to control ($p= 0.02$) (Table 3). A previous study suggested that color is the single most important sensory characteristic of food, as it sets consumers' expectations of the likely taste of that food (Thomson et al., 2002). Appearance is a strong contributor to 'overall liking' (Ho, 2019). It could be that the relatively dark color of the 5% ginger pasta did not meet consumers' expectations of the standard light colour of pasta, hence affected their experience contributing to low overall ratings of the product. This result is consistent with previous work, which revealed that the panelists prefer cereal products that are "less yellow in color" (Khan, Yousif, Johnson, & Gamlath, 2014). A meta-analysis of the sensory acceptance of fibre-enriched cereal foods showed that fibre enrichment lowered appearance acceptability, but that it depended on format and base acceptability (Grigor et al., 2016). Appearance is a strong contributor to 'overall liking'. Enrichment of wheat pasta with fibre changed the expectation of what the product would look like (Laureati, Conte, Padalino, Del Nobile, & Pagliarini, 2016) and the same could occur in the case of ginger enrichment. Despite a reduced liking of the 5% ginger pasta color, the other sensory attributes were not lower at a statistically significant level.

307 The textural attributes maybe associated with cooking time, however we found that (Ho, 2019)
308 with ginger did not change OCT time (9.5 min) or percentage cooking losses of (8.30%) for all
309 samples (data not shown). We did not measure instrumental texture or colour for the samples.
310 Results suggest that the addition of ginger to pasta did not affect product acceptability. This
311 supports observations from previous studies which reported the highest sensorial acceptability
312 for products (pasta and bread) enriched with 3% ginger among other products containing
313 different levels of ginger (Spence, 2015).

314 **3.3 Satiety trial**

315 Figure 4 illustrates the changes in satiety measures calculated by Rasch analysis for ten
316 panelists. There were no observable differences in the changes in the mean Rasch satiety
317 measure between the control and the ginger-enriched pasta. This was confirmed from the
318 result of the repeated measures ANOVA, indicating no significant difference of the effect of the
319 addition of ginger over time on the Rasch satiety measure, after applying a Greenhouse-Geisser
320 correction. Three panelists were excluded because when measuring the Rasch satiety, panelists
321 7, 8 and 9 showed non-typical response curves (supplementary data S1). For example, Rash
322 satiety measures for the control sample continued to steadily increase in 45 minutes (Panelist
323 7) and 75 minutes (Panelist 8) after consumption of the meal. A similar response curve was
324 noted for the pasta sample with ginger for Panelist 9, who continued to increase up to 60
325 minutes after consumption.

326 A secondary analysis was subsequently conducted to examine if these unusual satiety response
327 curves had an effect on the original analysis with seven panellists (Figure 5). Although there was
328 some indication that the ginger-enriched pasta sample had higher mean Rasch satiety measures

than the control sample in all time points after consumption, the repeated measures ANOVA found no significant differences ($p=0.9410$). The satiety analysis did not reveal any significant differences in postprandial satiety between both samples, although ginger pasta seemed to have higher overall satiety scores than control pasta. This finding is inconsistent with previous studies, which found that the consumption of 2 g of dried ginger in capsule form or as a hot beverage significantly increased postprandial satiety (Mansour et al. (2012); Taghizadeh et al., 2017).

Furthermore, several studies investigated the effect of the form of food on satiety and found that soups have a higher satiating effect than their solid equivalents (Mattes, 2005; Pan & Hu, 2011). This finding could potentially explain the lack of a statistically significant effect of the ginger-enriched pasta on satiety, compared to the positive results found by Mansour et al. (2012) using the same amount of ginger. The food matrix is likely to impact the bioactivity of ginger, as has been shown for other bioactives (Bub et al., 2019) and matrices (Phongnarisorn et al., 2018).

Notably, three panelists (7,8 and 9) had different satiety curves compared with others, which maybe because of the individual differences in the perception of hunger and fullness (supplementary data S1). These differences may be attributed to variations in the sensitivity to visceral signals that indicate the state of the stomach (Stevenson, Mahmut, & Rooney, 2015). It must be noted that the participants were all given the same portion size (i.e. it was not ad libitum). Increased food portion size is associated with increased energy intake, and individuals may have different portion perceptions (O'Brien, McNulty, Nugent, Gibney, & Livingstone, 2011; Rolls, Roe, Kral, Meengs, & Wall, 2004).

Further work should evaluate the mechanisms of how ginger impacts satiety and other aspects of energy balance. This can include a better understanding on individual responses, including the effects of age, gender and adiposity. Higher doses of ginger in different food matrices could also be formulated and tested over more extended periods. The role of sensory-specific satiety responses of ginger-enriched food products should also be explored.

4 Conclusion

In conclusion, 6-, 8-, 10-gingerol, 10-shogaol are present in commercial ginger powders with minor variations between samples. Ginger-enriched pasta was generally well accepted by consumers, with only the 5% ginger pasta recording lower acceptability for colour. All other sensory attributes were not stastically different. Consumption of 3% ginger-enriched pasta, containing approximately 2 g of ginger powder per portion, did not increase satiety in human volunteers.

Author Contributions

P. Ho and C. Orfila designed and supervised the study. M. Wu, and S. Viney run chromatography analyses. H. Gani made the pasta samples and performed the sensory and satiety human trials. P. Ho performed Rasch analysis and M.Wu and C. Orfila drafted the manuscript with input from all authors.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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Data Availability Statement

The data that support the findings of this study are openly available at the University of Leeds:

Mengyao Wu, Hanis Gani, Wasan Marafie, Sara Viney, Peter Ho and Caroline Orfila (2021):

Ginger pasta satiety - raw data. [Dataset] https://doi.org/10.5518/1027

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585 **Table 1 - Identification of the key compounds in ginger powders in the chromatograms.**

Peak no.	Retention time (min)	Ion Mass	Mode	Compound
1	1.00	293	Negative	6-gingerol
2	1.28-1.38	321	Negative	8-gingerol
3	1.67-1.82	331	Negative	10-shogaol
4	2.13-2.20	349	Negative	10-gingerol
5	1.38-1.49	275	Negative	6-shogaol

586

Table 2 - **Comparison of dry weight (mg/g) content of different bioactive in gingerol equivalents (GE) for five commercial ginger powder samples**

Sample[1]	6-gingerol[2]	8-gingerol[2]	10-gingerol[2]	6-shogaol[3]	10-shogaol[3]
A	13.6 ± 0.7[a]	2.6 ± 0.1[b]	2.5 ± 0.3[a]	-	2.0 ± 0.1[d]
B	14.6 ± 0.7[a]	2.9 ± 0.1[b]	1.6 ± 0.1[a]	-	5.0 ± 0.1[a]
C	7.8 ± 0.5[b]	2.1 ± 0.1[c]	3.1 ± 0.2[a]	1.5 ± 0.1[a]	4.2[b]
D	7.9 ± 0.3[b]	3.2[a]	2.5 ± 0.4[a]	1.9[a]	3.3[bc]
E	6.0 ± 0.2[c]	2.3[c]	2.4 ± 0.9[a]	2.3 ± 0.7[a]	3.3[c]

* Mean**± SD** with the same letter in superscript within the same column are not significantly different (p>0.05)

† SD not shown are < 0.01

[1] See table 1

[2] HSD Test

[3] LSRD Test

598 **Table 3 - Comparison of liking ratings for sensory attributes for the four pasta samples.**

Sample	Liking of Colour	Liking of Smell	Liking of Texture	Liking of Taste	Overall liking
Control	6.4 ± 1.5^{ab}	5.8 ± 1.9^{a}	6.6 ± 1.6^{a}	5.8 ± 1.5^{a}	6.0 ± 1.7^{a}
1% ginger	6.6 ± 1.5^{a}	6.4 ± 1.2^{a}	6.9 ± 1.3^{a}	6.6 ± 1.4^{a}	6.8 ± 1.35^{a}
3% ginger	6.1 ± 1.7^{ab}	6.4 ± 1.6^{a}	6.2 ± 1.7^{a}	6.2 ± 1.8^{a}	6.4 ± 1.7^{a}
5% ginger	5.5 ± 1.7^{b}	6.4 ± 1.5^{a}	5.8 ± 2.0^{a}	6.0 ± 1.8^{a}	6.2 ± 1.4^{a}

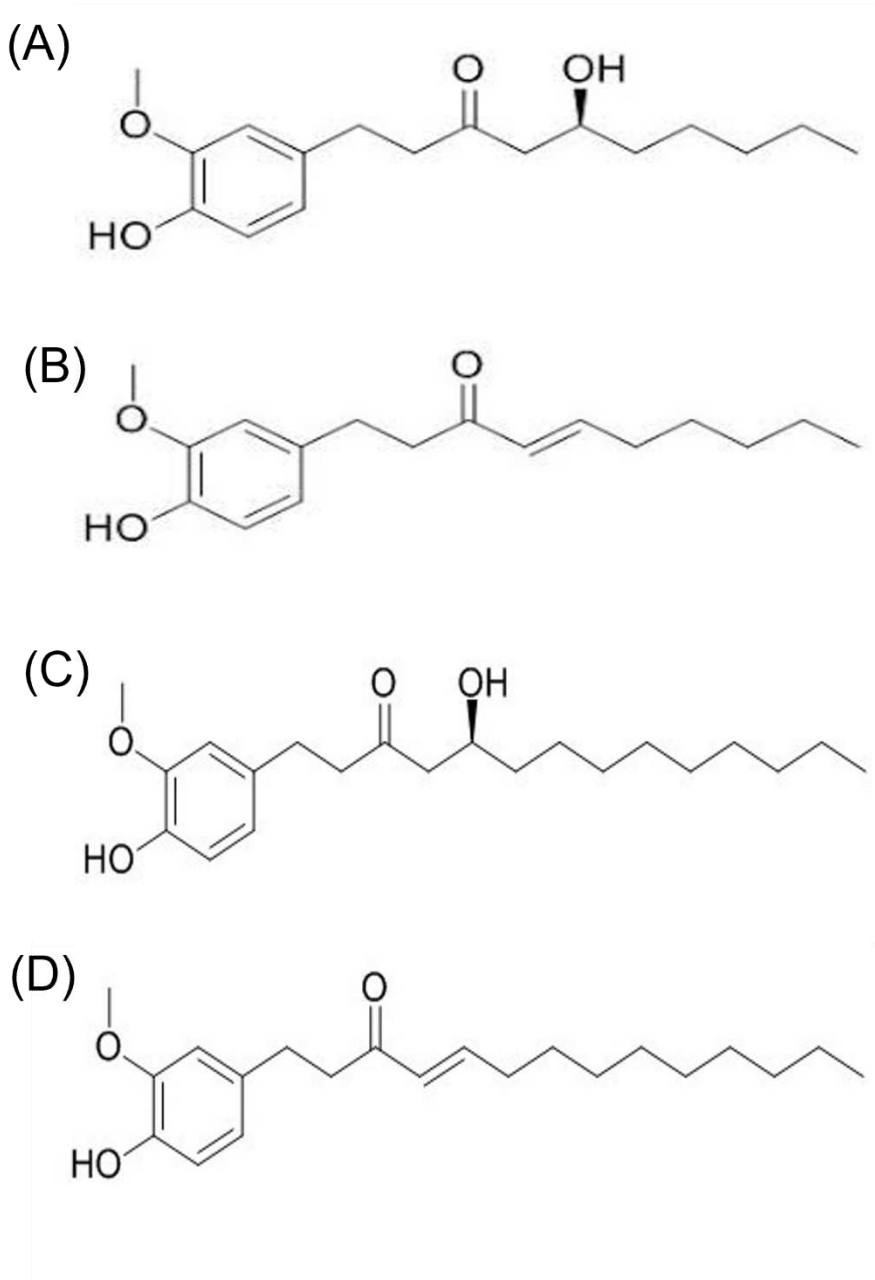
599 *__mean± SD__ with the same letter in superscript within the same column are not significantly

600 different (p>0.05).

601

602 **Figures**

603



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605 Figure 1 - Structures of the major bioactive components in ginger: (A) 6-gingerol, (B) 6-shogaol.

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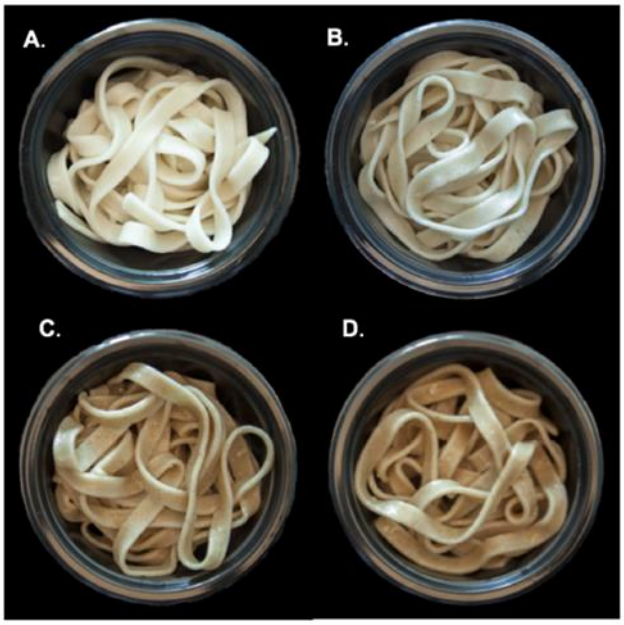

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609 Figure 2 - The four pasta samples provided in the sensory trial. A: control, B: 1% ginger, C: 3%

610 ginger, D: 5% ginger.

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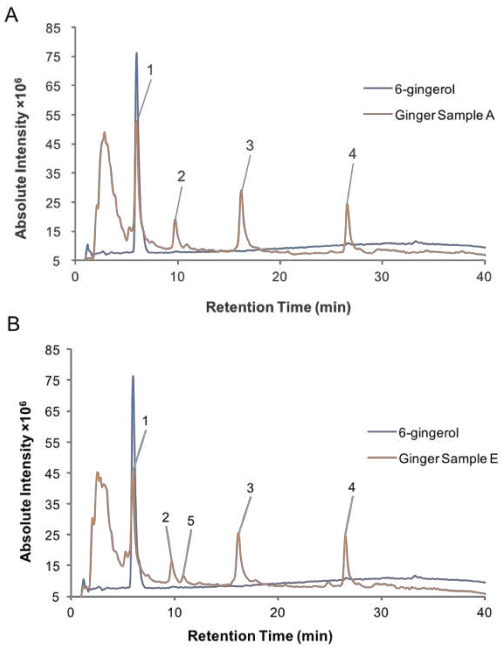

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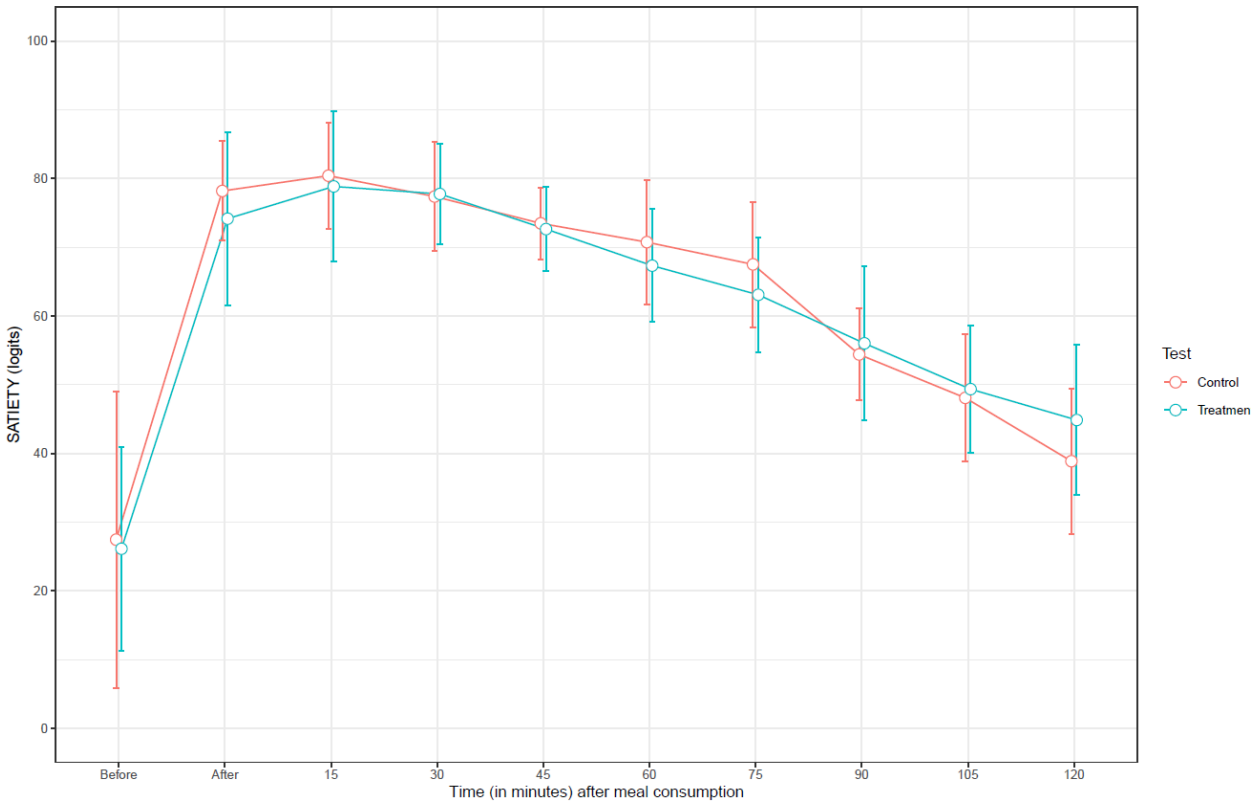
615 Figure 3 - HPLC-UV chromatograms showing the bioactive components in ginger sample A (A)

616 and E (B), detected at 282 nm. The blue line represented the 6-gingerol, which was used as

617 standard to analyze ginger powders while the orange one was for the ginger sample. Peaks 1 =

618 6-gingerol; 2 = 8-gingerol; 3 = 10-shogaol; 4 = 10-gingerol and 5 = 6-shogaol.

619



620

621 Figure 4 - Mean (±95% Confidence Interval) Rasch satiety measure for 10 healthy panelists for

622 control and 3% ginger (w/w) pasta.

623

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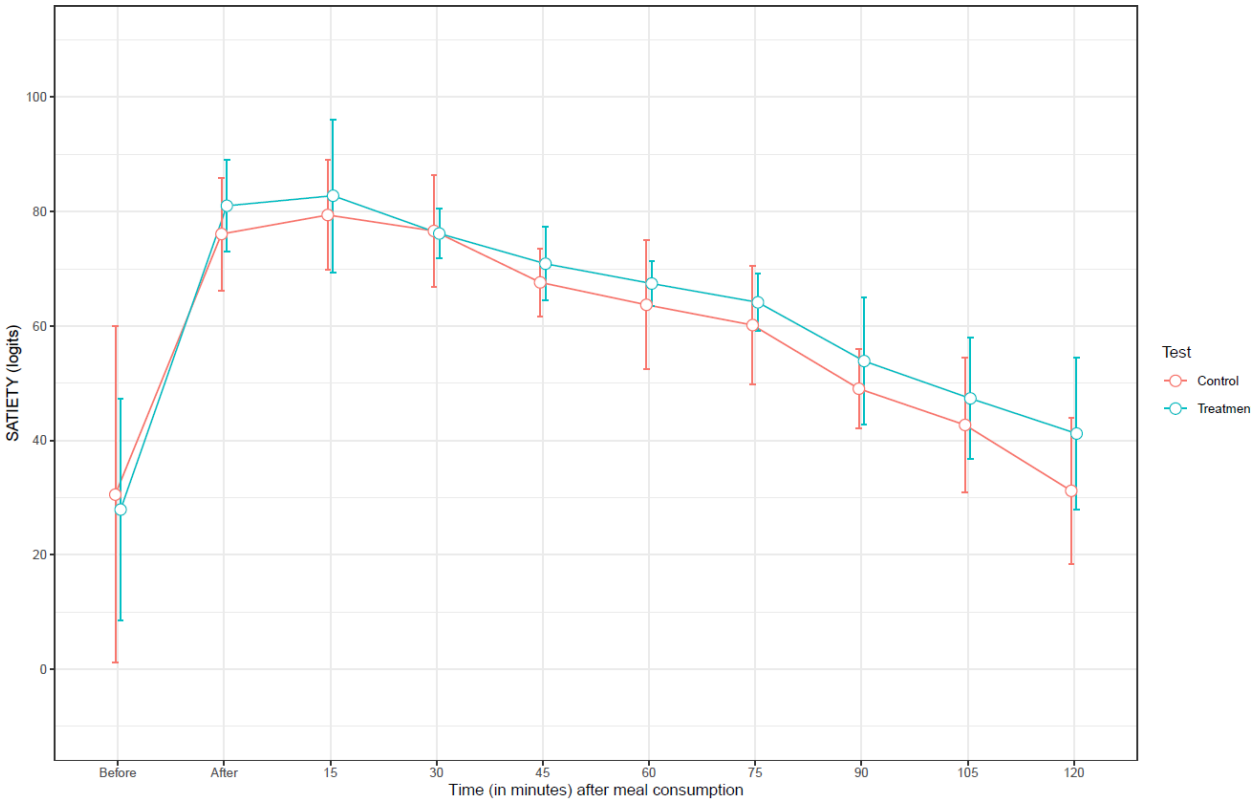
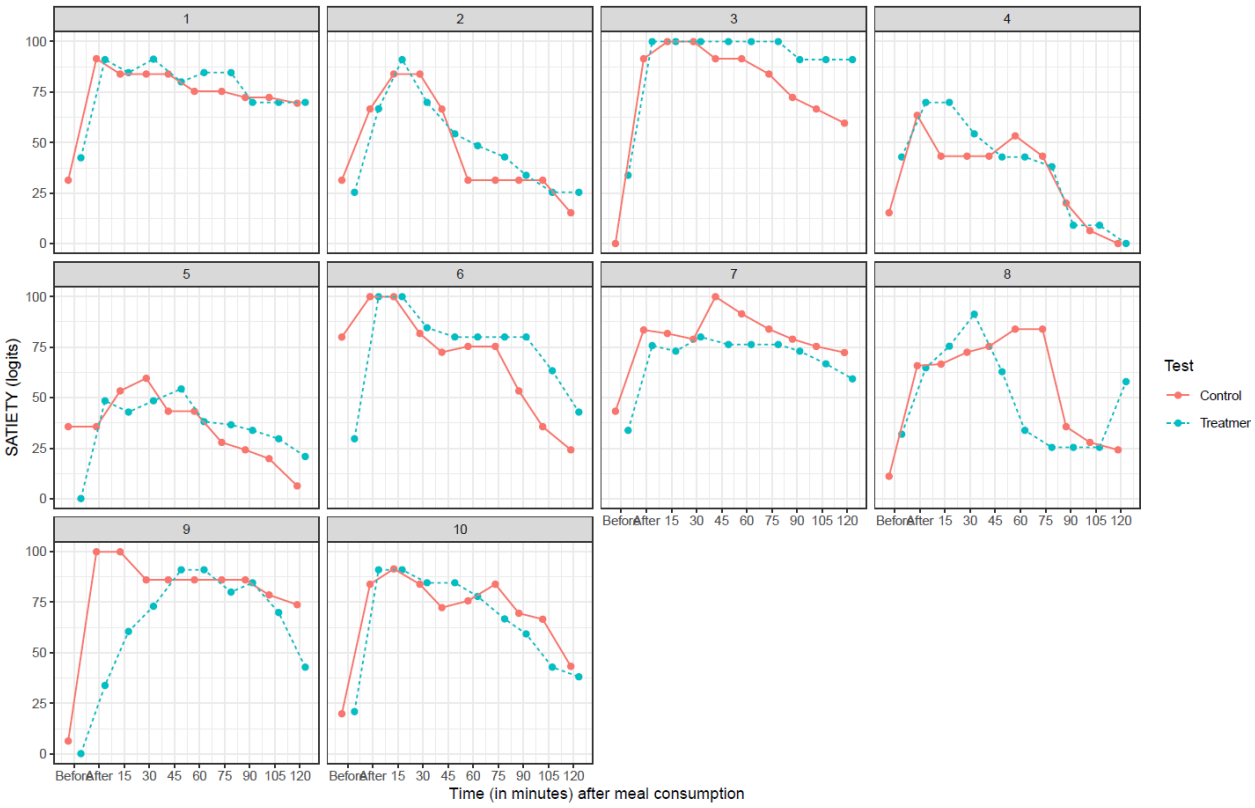


Figure 5 - Mean (±95% Confidence Interval) Rasch satiety measure for 7 healthy panelists after removing panelist 7, 8 and 9 for control and 3% ginger (w/w) pasta.



Supplementary Data Figure S1.

Figure S1 – Line graphs illustrated the satiety measures (in logits) for individual ten panelists for Control pasta (red lines) and ginger-enriched pasta (turquoise dashed lines). The satiety measures were plotted at time points Before, immediately after (After) and at every 15 minutes up to 120 minutes after meal consumption.