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The Effect of Consumption Volume on Profile and Liking of Oral Nutritional Supplements of Varied Sweetness: Sequential Profiling and Boredom Tests

L. Methven[a*], K. Rahelu[a], N. Economou[a], L. Kinneavy[a], L. Ladbrooke-Davis[a], O. B. Kennedy[a], D. S. Mottram[a] , M. A. Gosney[b]

[a]Department of Food and Nutritional Sciences, University of Reading, Whiteknights, Reading RG6 6AP, UK

[b]Clinical Health Sciences, University of Reading, London Road, Reading, Berkshire, RG1 5AQ

*Corresponding author. Fax: +44 (0)118 9310080. E-mail address: l.methven@reading.ac.uk

Running Title: Sequential Profile and Liking of Oral Nutritional Supplements

Abstract

Oral nutrition supplements (ONS) are routinely prescribed to those with, or at risk of, malnutrition. Previous research identified poor compliance due to taste and sweetness. This paper investigates taste and hedonic liking of ONS, of varying sweetness and metallic levels, over consumption volume; an important consideration as patients are prescribed large volumes of ONS daily. A sequential descriptive profile was developed to determine the perception of sensory attributes over repeat consumption of ONS. Changes in liking of ONS following repeat consumption were characterised by a boredom test. Certain flavour (metallic taste, soya milk flavour) and mouthfeel (mouthdrying, mouthcoating) attributes built up over increased consumption volume ($p \leq 0.002$). Hedonic liking data from two cohorts, healthy older volunteers (n=32, median age 73) and patients (n=28, median age 85), suggested such build-up was disliked. Efforts made to improve the palatability of ONS

must take account of the build up of taste and mouthfeel characteristics over increased consumption volume.

Keywords: oral nutrition supplements, sensory attributes, sequential profile, boredom test

1. Introduction

Malnutrition is a recognised problem in the elderly population, especially in hospitalised subjects; 60% of older people are at risk of malnutrition, or their situation worsening, in hospital (Age Concern, 2006). Identification and treatment of malnutrition in this high-risk group is extremely important to reduce the risk of disease, prevent worsening of any existing conditions and to maintain an optimum quality of life (O'Flynn, Peake, Hickson, Foster and Frost, 2005). Oral nutrition supplements (ONS) are supplementary oral dietary "food" routinely prescribed in-between meals to help improve the nutritional status of those with, or at risk of, malnutrition (Lochs et al, 2006). A review of sixty-two intervention trials (10,187 participants) by Milner, Potter, Vivanti and Avenell (2002) found ONS supplementation to produce consistent weight gain (in 42 trials), and decreased relative risk for mortality in trials where participants were undernourished (n=2461).

It has been suggested that the success of ONS may depend on consumption of sufficient quantities over an extended time period (Rahemtulla et al., 2005). A study investigating the effect of quantity of ONS consumed on weight loss and lean tissue in cancer patients, identified a failure to achieve the desired supplement intake prevented patients from obtaining important clinical benefits (Fearon et al., 2003). Gosney (2003) indicated that compliance of ONS can be low, thus limiting the success that can be achieved from prescribing ONS. A 24-hour study of 96 elder care ward patients found that two-thirds of the patients given ONS drank less than 50% of the carton resulting in 63% of ONS being wasted. Poor compliance with ONS has been demonstrated previously; Nolan (1999)

reported average wastage of two different ONS to be 41 % and 44% and Stableforth (1986) showed that elderly patients with femoral neck fractures only tolerated limited amounts of ONS which meant that large calorie deficits remained. Bolton et al (1992) compared the long term palatability of three commercial ONS products with cancer patients and found that 54% of patients discontinued the trial for flavour reasons. In the 2003 study, Gosney (2003) found the greatest wastage of ONS was found in patients who disliked the taste (72%). Of the 67% of patients who completed questionnaires, 56% said they did not like the products and specific dislikes were taste (25%), texture (19%) and sweetness (38%). Other factors that were thought to decrease compliance with ONS include a lack of thirst, chemosensory changes associated with ageing, the unfamiliarity of cartons to elderly people, in comparison to the frequently available cups of tea, and frequent spillage from cartons as a result of decreased dexterity (Gosney, 2003). Taste fatigue, which tends to occur when ONS are consumed regularly over prolonged periods, is thought to contribute to poor compliance (Rahemtulla et al., 2005).

A recent study reported age-related differences in preferred sweetness level, which were in-line with increased detection and recognition thresholds for sweetness; an overall dislike of ONS and dislike of the sweetness level of ONS vanilla products (Law, Gosney and Kennedy, 2006; Law 2006). Literature on age related taste threshold changes, and potential affects on food preference are somewhat contradictory. A number of studies have shown sweet taste threshold to increase with age (Zandstra and de Graaf, 1998; Mojet, Heidema and Christ-Hazelhof, 2003; Fukunaga, Uematsu and Sugimoto, 2005), whilst other studies have found no significant age-related decline in sweet perception (Kaneda et al, 2000; Koskinen, Kälviänen and Tuorila 2003). Mojet, Christ-Hazelhof and Heidema (2005) found no correlation between threshold sensitivity and optimal liking concentration for any basic taste stimuli; however Zandstra and de Graaf (1998) did find a trend for high

optimal concentrations of sucrose and orange flavour in drinks for elderly subjects compared to younger adults.

Development of ONS with lower sweetness, by replacing sucrose with an alternative saccharide, palatinose^{TM} (α-D-glucopyranosyl-1,6-fructose), led to segmentation in preference between consumers who liked the less sweet variants, and those who liked the sweeter control (Methven et al, 2008). The study noted that further work was needed to investigate if there was a difference in liking between ONS of different sweetness levels on consumption of greater quantities, in line with the typical pack size (200 ml). However, there appears to be no study in the literature which examines the specific sensory attributes of ONS or their affect on liking over increasing consumption volume; this latter point is likely to be extremely important in identifying potential reasons for the rejection of ONS, which may arise when greater quantities of ONS are consumed.

In order to measure change in sensory perception over consumption time, time intensity profiling (TI) is typically used (Duizer, Bloom and Findlay, 1997), however TI can only characterise a maximum of two attributes per sample. A temporal dominance method (Labbe, Schlich, Pineau, Gilbert and Martin, 2009) has been developed recently, although one potential drawback of this method for products such as ONS could be that attributes of secondary rather than primary dominance might be important determinants of product liking. A previous study used progressive profiling (Jack, Piggott and Paterson, 1994) to profile the textural attributes of hard cheese during mastication. In the present study this idea has been progressed, with the help of Compusense, to a sequential profiling method where up to five attributes are scored over consecutive tastings, at regimented time intervals.

The present study aimed to investigate the effect of consumption volume on the sensory profile and liking of ONS. In addition the study aimed to investigate if modifications of sweetness and metallic levels could improve the hedonic liking of ONS.

2. Materials and methods

The commercial ONS (CONS) used was Ensure Vanilla Plus (Abbott Nutrition, Maidenhead, UK), and Lactisole (sodium 2-(4-methoxyphenoxy)-propanoate) was used as a sweetness suppressor (Domino Sugar, American Sugar Refining, USA). Standard ingredients used in the manufacture of ONS were as follows : glucose syrup (Cerestar 01921, Cargill, Manchester, UK), sucrose (Tate and Lyle, London, UK), high oleic sunflower oil, canola oil, and rape seed oil (Cargill, Liverpool, UK), sodium caseinate (Bacarel, Stone, UK), milk protein concentrate (MPC85, Bacarel, Stone, UK), soy protein isolate (ProFit SI90, Food Ingredient Technologies, Bedfordshire, UK); soy lecithin (Emulpur IP, Cargill, Hamburg, Germany); commercial blends of emulsifier, vanilla flavour, vitamins and minerals were supplied by Abbott (Abbott Nutrition, Columbus, USA). Mineral water (Harrogate Spa, UK) and medium sliced white bread (Hovis, Windsor, UK) were used as palate cleansers in sensory testing. Sucrose (Tate and Lyle, London, UK) and iron sulphate heptahydrate (Fluka, Sigma Aldrich, Germany) were used for taste threshold tests.

2.1 Manufacture of ONS modifications

Preparation of suppressed sweetness ONS (SSONS) was carried out by adding the sweetness suppressor lactisole to the commercial vanilla ONS products (0.003mg lactisole/100ml Ensure Plus Vanilla). In addition, ONS samples were manufactured on a pilot scale ultra heat treatment (UHT) plant. The standard formulation (PPSONS) consisted, per 100g, of glucose syrup (17g), sodium caseinate (3.5 g), sucrose (2 g), oil blend (4.4g), milk protein concentrate (1.8 g), soy protein isolate (1.3 g) and a commercial blend of emulsifier, flavour, vitamins and minerals. Ingredients were blended at 60 °C prior to ultra heat treatment by indirect steam injection at 140ºC for 27 seconds. Two formulations were manufactured, the standard formulation (PPSONS) and a formulation without mineral mix(PPNONS). The total solids content of all products measured by

refractometer, was 32%. The pH ranged from 6.6 to 6.8 and density ranged from 1.05 and 1.09 g/ml. All samples were stored at 4ºC prior to tasting.

2.2. Sensory methods

All sensory evaluation (sensory panel, healthy older volunteer and patient groups) was carried out at room temperature (25 °C +/- 2°C), product temperature was allowed to equilibrate to room temperature; actual product temperature at serving was 20 °C (+/- 3 °C).

2.2.1 Sensory, volunteer and patient groups

This study employed three different groups to assess the products; a trained sensory panel, a healthy older volunteer panel and a patient group. The trained sensory panel comprised 12 adults (11 females, 1 male; median age 42 years, range 33-59), expert in profiling techniques, all had over 1 years experience and had been given a minimum of 4 hours training on profiling of ONS. The healthy older volunteer panel comprised 32 healthy, older, free-living volunteers (20 females, 12 males; median age 73 years, range 66-88). The patients were 28 older adults (11 female, 17 male; median age 85, range 71-90) in hospital with a variety of medical conditions. Permission for the studies with the first two panels was granted by the University of Reading Research Ethics committee and the study with patients was approved by the Berkshire National Research Ethics committee (NRES 08H0505176). All participants gave written informed consent prior to taking part in the study.

Quantification with the trained panel took place in isolated booths, under artificial daylight unless specified otherwise. Healthy older volunteer panels took place in a central location, using isolated tables; lighting was standard fluorescent lighting. Patients were studied individually at their bedside, under standard hospital lighting conditions..

2.2.2. Sequential profiling

155 The trained sensory panel characterised five specific sensory attributes of various ONS in
156 a sequential profile. This is a descriptive profiling method developed to determine the
157 perception of sensory attributes upon repeat consumption of ONS over time. Panellists
158 tasted eight consecutive aliquots (5 ml) of each ONS sample and were instructed to score
159 the selected five attributes following each of the eight tastings. For each tasting, panellists
160 were also instructed to score the same five attributes as after-effects, following 30 s and
161 60 s time delays. A two minute time delay was enforced between samples. Panellists
162 scored each attribute on unstructured line scales with the appropriate anchors.
163 Compusense five was used to design and run the profile and capture data.
164 The five attributes scored were sweet, metallic, soya milk flavour, mouthcoating and
165 mouthdrying. In a previous full quantitative descriptive analysis (QDA) profile of four
166 commercial products (Ensure Vanilla Plus, Abbott Nutrition UK; Fortisip Vanilla, Nutricia
167 Clinical Care UK; Resource Shake Vanilla and Clinutren Vanilla, Nestle Nutrition France)
168 sweet taste was found to be significantly different between samples ($p=0.03$), soya milk
169 flavour was only found to be significant as an aftertaste ($p=0.03$) (data not shown). QDA
170 did not reveal significant differences in metallic taste, mouthdrying or mouthcoating; and
171 yet these characteristics were thought to be distinct in ONS. The trained panel commented
172 on this and noted that these attributes appeared to last in the mouth beyond the profiling
173 session. It was, therefore, decided to study metallic, mouthdrying and mouthcoating,
174 alongside sweet taste and soya milk flavour, using the sequential profile.
175 Sequential profile data was collected for the following ONS: standard commercial vanilla
176 ONS (CONS) (Ensure Plus), sweetness suppressed vanilla ONS (SSONS; Lactisole in
177 Ensure; 0.003g/100ml), pilot ONS control (PPSONS, with vitamins and minerals) and pilot
178 ONS with no mineral addition (PPNONS).
179 The commercial products (with and without lactose) were tasted in one week, in replicate,
180 samples presented in a balanced order. The pilot plant products were presented in

replicate in a separate week, in balanced order. Samples were coded with 3-digit numbers; however, all samples which were the same received the same code (panellist not blinded to sequential protocol). Still mineral water and bread were provided as palate cleansers in-between product samples (not between the eight consecutive aliquots of the same sample). Panellists were instructed to drink all the sample volume presented and were not permitted to drink water during sequential profiling.

2.2.2.1 Sequential profiling method validation

In order to validate the sequential profiling method a further evaluation of CONS was carried out, where panellists were given eight consecutive aliquots (5 ml) of the same sample, however, they were blinded to the test procedure, each aliquot had a unique three digit code and these were presented in a balanced order. Time of tastings and scoring after-effects were controlled in the same manner as the sequential profile.

2.2.3. Taste detection threshold tests

For all groups, taste thresholds were determined by forced-choice ascending concentration method (ASTM, 1997). Each assessor received a series of 3-alternative forced choice (3-AFC) sets, each set comprised a taste solution (prepared in mineral water) and two water samples at room temperature (balanced presentation order). Sets were presented once, in order of increasing concentration, increased by a geometric progression of two. Five iron sulfate (metallic) solutions were prepared from 2.8 to 44.8mg/L, six sucrose solutions were prepared from 0.34 to 10.88g/L and ranges were within those recommended by ISO 3972 (ISO, 1991). Patients received only sweet solutions and only in five different concentrations, from 0.68 to 10.88 g/L. Samples were coded with 3-digit random numbers. For metallic solutions, red light conditions were used for the trained panel and sample cups with sip lids were used for the older volunteer panel. Volunteers were instructed to choose the odd–one-out and comment on the taste which they perceived in the most different sample. Individual detection thresholds were

calculated as the geometric mean of the detection threshold and the concentration preceding this.

2.2.4 Hedonic tests

Hedonic liking data was collected from 32 healthy older adults and 28 patients, using a modified boredom test (Köster and Mojet, 2007). This was used to characterise any changes in liking of ONS following repeat consumption and to compare the liking of pairs of samples. All subjects began by tasting 5ml of each of two samples (random 3 digit coded, balanced presentation order) and scored liking for each on a 9-point hedonic scale (initial liking), scaled from dislike extremely to like extremely. They then tasted a series of eight consecutive 5ml aliquots of one sample (balanced presentation across volunteers, samples coded by symbol) and were permitted to drink mineral water, if desired after tasting the first four aliquots of the series of eight. Subjects subsequently tasted a further 5ml of each of the two samples (random 3 digit coded, balanced presentation order), re-scored their liking for each on the 9-point hedonic scale (final liking) and were asked to state the sweetest sample of the final two samples. Subjects consumed 60ml of ONS in total. The boredom trial was modified for the patient group in that the central eight 5 ml aliquots were replaced by a central cup containing the full 40 ml of sample as it was impractical to present 12 small cups on one tray at a patient's bedside. Patients were also their sugar usage in tea and/or coffee.

2.3. Statistical analysis

SENPAQ (version 3.2) was used to carry out analysis of variance (ANOVA) and principal component analysis (PCA) of sensory panel profiling data. In order to determine the effects of time from the sequential profiling, three-way ANOVA was carried out in XLSTAT (version 2009.1.02), using sample (n=2), assessors (n=12) and time (n=8) as explanatory variables. Non-parametric testing on the liking data and ANOVA on taste threshold data were also carried out in XLSTAT (version 2009.1.02).

3. Results and discussion

3.1. Sensory data

3.1.1. Sequential Profile

3.1.1.1 Standard ONS and sweetness suppressed ONS

Sequential profile data was collected for commercial ONS (CONS) to characterise if changes in perception of sensory attributes occurred over repeat consumption of a typical commercial ONS. Sequential profiling was also carried out on the sweetness suppressed variant (SSONS) to determine the effect of sweetness suppression on the perception of sensory attributes over repeat consumption; the interest in sweetness suppression was triggered by previous research which identified a disliking for the sweet taste of ONS (Gosney, 2003; Methven et al, 2008).

Figure 1 illustrates how perception of the five selected sensory attributes varied with repeat consumption of standard vanilla Ensure ONS (CONS). Mouthdrying, metallic, mouthcoating and soya milk flavour built up significantly over time ($p<0.0001$, $p=0.002$, $p<0.0001$ and $p<0.0001$ respectively). Unlike the aforementioned attributes, sweetness did not build over repeat consumption, it peaked at sips and decreasing as after-effects. Figure 2 compares the standard sweet (CONS) and the sweetness suppressed (SSONS) variants for three attributes. The SSONS was perceived as significantly less sweet ($p<0.0001$; initial mean scores 24 and 48 respectively). It was also significantly more mouthdrying ($p<0.0001$), although the difference was less substantial as tastings progressed, (mean scores at second sip of 42 and 36 respectively). It is likely that the sweeter sample is perceived as less mouthdrying due to the sweet taste interfering with the drying perception; a previous study found sweetened soymilk to be less astringent than its unsweetened counterpart (Courrelongue, Schlich and Noble, 1999). There was no significant difference in the metallic perception of the two products, the soya milk flavour or mouthcoating (data not shown).

3.1.1.2 ONS control and No-Mineral ONS formulations

It was hypothesised that the minerals added to ONS during manufacture may contribute to both astringent and metallic tastes. The mineral supplementation added to ONS contains iron sulfate, known to impart metallic taste (Lim and Lawless, 2006). Minerals, particularly zinc, are also known to impart astringent properties to solutions (Yang and Lawless, 2005). To test the hypothesis, a control ONS formulation (PPSONS) that contained the full mineral supplement and a formulation that had no mineral supplementation (PPNONS) were manufactured. Figure 3 demonstrates the mouthdrying and metallic profiles of these two ONS products. As with commercial ONS; metallic and mouthdrying built up significantly over consumption time ($p=0.001$ and $p<0.0001$ respectively) for both products. On first consumption (5 ml) the mineral free product had a lower mean for metallic taste (21.5 compared to 24.2) although the difference was not significant. Over all of the consumption period (eight 5 ml samples) the mineral free product (PPNONS) was significantly less metallic ($p<0.0001$), although the difference in overall means across time was very small (25.2 and 26.7 respectively). It is therefore noted that although the minerals added to the ONS formulation do contribute to the metallic taste, expected as the supplementation contains iron sulfate, this cannot be the only source of metallic taste in the products. The mineral supplementation is not thought to be the major source of mouthdrying as the two products did not differ significantly in mouthdrying. It is hypothesised that another source of mouthdrying could be the milk proteins typically used in ONS formulations. Previous studies have shown whey proteins to cause mouthdrying through precipitation onto the tongue (Sano, Egashira, Kinekawa and Kitabatake, 2005); alternatively proteolysis of on β-casein can yield γ-caseins which are associated with perceived dryness of milks (Harwalkar, Cholette, McKellar and Emmons, 1993).

3.1.1.3 Validation of the sequential profile

Given that panellists were asked to score the same attributes over time during sequential profiling, their expectation might be that certain attributes were expected to build up over time. However, in the first and subsequent sequential profile sessions four attributes (mouthdrying, metallic, mouthcoating, and soya milk flavour) were found to build with time, whereas sweetness did not. It was not thought likely that the panellists anticipated that certain attributes would build over time and others would not. To further validate the sequential profiling method, panellists were given eight consecutive aliquots of the same sample, and blinded to the fact that the samples were identical. Figure 4 demonstrates that the two methods did not give identical results. The panellists contributing to the data acquired by both methods were the same, however, the batch codes of the samples were different and the methods were run in different weeks. As the panellists were not using any reference standard, it is expected that absolute values for the samples varied between the methods; it is whether the trends differ that is important.

The two profiles (where panelists blinded to the sequential nature of the profile, and where they were not blinded) gave very similar trends for sweetness; there was a significant difference between results from the two methods ($p=0.001$) and no significant change over consumption time. For metallic taste, the panellists record a more substantial increase in metallic taste over consumption time when not blinded to the sequential profiling, however the trends for both methods was the same. There was a significant difference between the two methods ($p<0.0001$), but still a significant overall increase in metallic taste with time ($p<0.0001$), with the not-blinded sequential profile finding a mean increase of 19 (from 18 to 37) and the blinded sequential profile a mean increase of 9 (from 13 to 21). Similarly for mouthdrying and soy milk flavour (data not shown), there were significant differences in the results from the two methods ($p=0.01$, $p=0.05$), but a significant increase with increased consumption overall ($p=0.026$, $p<0.0001$). There was no significant difference between the methods for mouthcoating (data not shown) and an overall increase in

mouthcoating with increasing consumption (p=0.001). In conclusion, it was found that panellists may exaggerate increase in perception were they aware that they had performed a sequential profile; however, the significant changes found over time were the same whether panelists were blinded to the sequential nature or not.

Panellists received two ONS samples in one sequential profiling session; they therefore consumed 80ml per session. This amount is in line with typical volumes of ONS consumed in hospitals, as previously reported; Gosney (2003) identified that only 37% of ONS were consumed, which is approximately 80ml, assuming a typical pack size of 220ml. The data from the commercial sequential profiles is therefore likely to represent the sensory characteristics perceived by patients consuming similar volumes of these products.

3.1.2 Taste threshold tests

3.1.2.1 Metallic taste thresholds

Metallic detection threshold tests were conducted to identify whether older consumers could potentially identify the metallic attribute in the ONS, and to determine any difference in metallic threshold between younger and older adults (Figure 5). However, it was surprising that only 60% of the trained sensory panellists (median age 42) correctly identified any sample differences in the metallic threshold test; the group best estimated metallic threshold (geometric mean) for these panellists was 16mg/L. Forty percent of the sensory panellists could not detect metallic at the maximum concentration of 45mg/L. In comparison, only 32% of the healthy older volunteers (median age 73) correctly identified any sample differences in the metallic threshold test; the group best estimated metallic threshold for these volunteers was 26mg/L. The higher metallic detection threshold and higher proportion of non-detectors observed in the group of healthy older volunteers was expected as several studies have found elevated thresholds for taste and a diminished ability to discriminate between suprathreshold stimuli (Schiffman and Graham, 2000). However, the present study also questions the validity of using the 3-AFC test as a

suitable test for metallic taste threshold determination. Metallic taste tends to be noticed as an aftertaste and, as shown in the sequential profiling results, it builds with time and is difficult to clear from the palate. Therefore, false identification is likely to arise from the 3-AFC tests as a result of build up from previous samples tasted. If the sensory panellists were truly unable to detect iron sulfate as metallic at 45 mg/L, it is unlikely that they would detect metallic taste in the ONS where the iron levels are typically around 20 mg/L, unless most of the metallic taste perceived is not attributed to the iron sulfate. In a previous study (n=18, mean age 24) the group best estimated threshold for iron sulfate was 27.5 mg/L (99 mmol/L), with a large standard deviation of 125mg/L (452mmol/L) (Lim and Lawless, 2006); this study also used the 3-AFC test method.

3.1.2.2 Sweet taste thresholds

The mean sweet detection thresholds for the sensory panel (median age 42), healthy older volunteers (median age 73) and patients (median age 85) were 2g/L, 3g/L and 5.5 g/L respectively. The median age of the older volunteers and patients combined was 78 years. The distribution of sweetness thresholds is given in Figure 6, which suggests an increase in sweet taste threshold with increasing age, as supported by previous literature (Zandstra and de Graaf, 1998; Mojet et al, 2003; Fukunaga et al 2005). Indeed, when the healthy older volunteers were divided into two age categories; 66 to 77 and 78 to 88 (below and above overall median age), the sweet taste thresholds were 2.6 and 4.1 g/L respectively, although this difference was not significant. The higher taste thresholds of the patients compared to the older volunteers cannot be explained by age alone. Combining the healthy older volunteer and patient data together and analysing for the effect of group (healthy or patient) and age (< or > 78) by ANOVA; the group had a significant effect on sweet taste threshold ($p=0.005$), whereas the age did not. It is, therefore, hypothesised that illness and medication have a greater effect on sweetness thresholds than age. Illness and medication are known to taste thresholds increases as well as a wide range of taste

disturbances; this area has been previously reviewed by Schiffman (Schiffman and Zervakis, 2002). The patient cohort were prescribed an average of 4.5 medications (range 0-11) of which an average of 1.4 (range 0 to 3) were known have the capacity to cause taste disturbance (British National Formulary, 2009). The healthy older volunteers were prescribed an average of 2.1 medications (range 0-11) of which an average of 0.7 (range 0 to 3) had the capacity to cause taste disturbance.

3.2. Hedonic data

3.2.1. Boredom test

Mean liking scores for standard ONS (CONS) and the sweetness suppressed ONS (SSONS), at start and end of the boredom test, are given in Table 3. With both older cohorts, the mean initial liking of the standard vanilla ONS was significantly higher than the initial liking of the sweetness suppressed ONS ($p \leq 0.05$). However, there was a difference between the cohorts in their change in liking from start to end of the boredom test. The healthy volunteer mean liking of the standard ONS significantly decreased during the boredom test from 6.3 to 5.0 ($p \leq 0.001$). This was irrespective of whether they received 40 ml of CONS or SSONS during the boredom test (sample received in-between the initial and final liking pairs). The liking of the SSONS did not change over time for the volunteer cohort. In contrast, there was not a decrease in liking of the standard product during the boredom test for the patient cohort. However, their liking of the SSONS did decrease significantly over the boredom test, irrespective of the boredom sample ($p \leq 0.05$). One point to note in carrying out the boredom trials with the patient group, as the central boredom sample was contained in one cup as a 40 ml sample, rather than as eight individual 5 ml samples, there was a tendency for patients not to consumer the full 40 ml which is likely to have reduced any effect of change in liking over the boredom test.

The main conclusions from the boredom liking tests were that overall liking of the CONS was greater than the SSONS. As liking was found to decrease with repeat consumption, it

388 is likely that consumption of a typical pack volume may reduce liking of the products even
389 further. It is hypothesised that the attributes of mouthdrying and metallic which were found
390 in the sequential profiling study to build substantially over consumption volume may, in
391 part, cause the reduction in liking.

392 **3.2.2 Consideration of sugar usage and sweetness thresholds on ONS liking**

393 There were 17 patients who regularly took sugar in their tea or coffee and 11 who did not.
394 There was no correlation between sugar usage and sweetness threshold. In addition,
395 there was no correlation between sugar usage or sweetness threshold and liking scores
396 for the standard ONS in comparison to the sweetness suppressed variant. The later point
397 supports the previous study by Mojet et al (2005) which found sweetness thresholds not to
398 correlate with preferred sweetness level. The volunteers and patients could determine that
399 the standard ONS sample was sweeter than the SSONS ($p<0.0001$; 26 out of 32
400 volunteers; 25 out of 27 patients). Healthy older volunteers and patients who incorrectly
401 identified which sample was the sweetest, did not have the highest sweetness thresholds;
402 implying that the sweetness of the products was above each individuals sweetness
403 threshold. This also demonstrates that sugar consumption in hot beverages did not impact
404 upon ONS sweetness perception.

405 **4. Conclusions**

406 Sequential profiling was used to characterise five attributes of vanilla dairy-based ONS
407 over repeat consumption. This highlighted a significant build up of mouthdrying, metallic
408 and mouthcoating attributes over a total consumption volume of 40 ml, which would not
409 have been found though a standard profiling study. Such build may have major
410 implications on the long-term, repeat consumption of these products, especially since
411 patients are often encouraged to drink up to 600ml daily. Liking of ONS, with both healthy
412 older and older patient groups, was found to diminish over repeat consumption (60ml),
413 suggesting that build up of taste and mouthfeel attributes over repeat consumption was

disliked. The combined use of sequential profiling and liking over repeat consumption (using a boredom test approach) is recommended as a methodology suitable for the exploration of products such as ONS which are known to have aftertastes.

Removal of the minerals from an ONS formulation did not significantly reduce mouthdrying and although the effect on metallic taste perception was significant, it was not substantial. Components other than iron sulfate, intrinsic to ONS, such as the calcium and milk proteins, may contribute to these attributes. In support of this, calcium salts have been shown to exhibit both astringent and metallic taste properties (Lawless, Rapacki, Horne and Hayes, 2003) and both whey protein precipitation and casein proteolysis products have been associated with mouthdrying (Sano et al, 2005; Harwalkar et al, 1993). Further research into the properties of ONS ingredients may help to elucidate potential causes of the build up of attributes over repeat consumption. If the build up can be reduced this may lead to improve palatability and consumption of ONS.

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Figure 1: Sequential profile of commercial vanilla ONS

Footnote figure 1:

[(a)]Sip 1–8, consumption point of 5 ml aliquots; AE1, AE2, after-effects at 30 s and 60 s post consumption of aliquots 1–8.

Figure 2: Sequential profiles of two sweetness variants of vanilla ONS

Footnote figure 2:

[(a)]Sip 1–8, consumption point of 5 ml aliquots; AE1, AE2, after-effects at 30 s and 60 s post consumption of aliquots 1–8. CONS = Standard commercial ONS ; SSONS = Sweetness Suppressed commercial ONS

Figure 3: Sequential profiles of two mineral variants of vanilla ONS

Footnote figure 3:

[(a)]Sip 1–8, consumption point of 5 ml aliquots; AE1, AE2, after-effects at 30 s and 60 s post consumption of aliquots 1–8. PPSONS = control pilot plant ONS; PPNONS = No mineral pilot plant ONS

Figure 4: Validation of sequential profiling, used to quantify three attributes of commercial vanilla ONS over eight consecutive (5 ml) consumptions

Footnote figure 4:

[(a)]Sip 1–8, consumption point of 5 ml aliquots; AE1, AE2, after-effects at 30 s and 60 s post consumption of aliquots 1–8. Blind= panellists not aware that consecutive samples were the same sample; Sequential = panelists aware profile was sequential

Figure 5: Frequency distribution of metallic taste detection thresholds for sensory panellists and healthy older volunteers

Figure 6: Frequency distribution of sweet taste detection thresholds for sensory panellists, healthy older volunteers and patients

Table 1. Liking Scores for Standard Commercial (CONS) and Sweetness Suppressed (SSONS) ONS at Initial and End Tasting, following a Boredom Test, for a healthy older volunteer cohort (n=32) and a patient cohort (n=28)

		Mean Liking[a] (Irrespective of sample used for 40ml boredom)			Mean Liking[b] (Participants consuming CONS for Boredom phase)			Mean Liking[c] (Participants consuming SSONS for Boredom phase)		
Cohort	Product	Initial	Final	Sig[d]	Initial	Final	Sig[d]	Initial	Final	Sig[d]
Healthy	CONS	6.3±1.7	5.0±1.9	***	6.4±1.4	5.6±1.4	*	6.1±2.0	4.3±2.2	**
Older	SSONS	5.2±1.9	5.5±1.9	ns	5.2±1.7	5.0±1.6	ns	5.3±2.2	6.1±2.1	ns
Volunteers	Sig[e]	*	ns		*	ns		ns	ns(p=0.08)	
Patients	CONS	6.8±1.8	6.7±1.8	ns	6.9±1.3	6.3±1.2	ns (p=0.06)	6.8±2.2	7.0±2.1	ns
	SSONS	6.1±1.9	5.2±2.3	*	6.2±1.3	4.9±2.0	*	6.1±2.2	5.4±2.5	ns
	Sig[e]	*	***		ns	*		ns (p=0.06)	*	

[a]Preference data represents mean scores ± standard deviation, from a 9-point hedonic scale for all volunteers; [b]18 volunteers and 12 patients consumed CONS during the boredom phase, [c]14 volunteers and 16 patients consumed SSONS during the boredom phase [d]Significance of difference between initial and final liking, as shown by ANOVA: p<0.001 (***), p<0.01 (**), P<0.05 (*), not significant (ns). . [e]Significance of difference between CONS and SSONS.