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Research report

Enhancing consumer liking of low salt tomato soup over repeated exposure by herb and spice seasonings ☆

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ABSTRACT

There is strong evidence for the link between high dietary sodium and increased risk of cardiovascular disease which drives the need to reduce salt content in foods. In this study, herb and spice blends were used to enhance consumer acceptability of a low salt tomato soup (0.26% w/w). Subjects (n = 148) scored their liking of tomato soup samples over 5 consecutive days. The first and last days were pre-and post-exposure visits where all participants rated three tomato soup samples; standard, low salt and low salt with added herbs and spices. The middle 3 days were the repeated exposure phase where participants were divided into three balanced groups; consuming the standard soup, the low salt soup, or the low salt soup with added herbs and spices. Reducing salt in the tomato soup led to a significant decline in consumer acceptability, and incorporating herbs and spices did not lead to an immediate enhancement in liking. However, inclusion of herbs and spices enhanced the perception of the salty taste of the low salt soup to the same level as the standard. Repeated exposure to the herbs and spice-modified soup led to a significant increase in the overall liking and liking of flavour, texture and aftertaste of the soup, whereas no changes in liking were observed for the standard and low salt tomato soups over repeated exposure. Moreover, a positive trend in increasing the post-exposure liking of the herbs and spices soup was observed. The findings suggest that the use of herbs and spices is a useful approach to reduce salt content in foods; however, herbs and spices should be chosen carefully to complement the food as large contrasts in flavour can polarise consumer liking.

Introduction

Sodium chloride is an important component of many food products used for taste, texture and preservation. In addition to eliciting salty taste (McCaughey & Scott, 1998), sodium chloride can suppress bitterness (Frijters & Schifferstein, 1994; Keast & Breslin, 2002), increase sweetness at low concentrations (Keast & Breslin, 2003) and enhance the perception of volatile flavour compounds (Ventanas, Puolanne, & Tuorila, 2010). However, dietary salt intakes are much higher than nutritional requirements in most countries (Brown, Tzoulaki, Candeias, & Elliott, 2009). There is strong evidence for a link between high dietary sodium and hypertension; thereby increasing the risk of cardiovascular disease (Cook et al., 2007; Strazzullo, D'Elia, Kandala, & Cappuccio, 2009; Tuomilehto et al., 2001). In western populations, approximately 75% of dietary salt is derived from processed food (Food Standards Agency, 2009). However, decreasing salt content in processed food products is a big challenge for the food industry as it has an adverse effect on product sensory profile and, hence, consumer acceptability (Breslin & Beauchamp, 1997). Currently, there are a number of approaches in use. Stealth or small step reduction is a promising approach; however, the amount of salt that can be reduced following this approach is limited (Girgis et al., 2003). Mineral salts such as potassium chloride, calcium chloride and magnesium sulphate have been used to substitute the salty taste of sodium chloride in a number of food products (Vanderklaauw & Smith, 1995), but they have undesirable aftertastes that limit their applications in food manufacturing (Liem, Miremadi, & Keast, 2011). The sourness of acids such as citric acid can be utilised to enhance the perceived saltiness (Hellemann, 1992; Little & Brinner, 1984) as can taste enhancers such as amino acids, monosodium glutamate, lactates, and yeast products (Ball, Woodward, Beard, Shoobridge, & Ferrier, 2002; Jinap & Hajeb, 2010) and salt associated odours (Lawrence, Salles, Septier, Busch, & Thomas-Danguin, 2009; Noble, 1996).

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Flavouring of foods using blends of natural herbs and spices is a preferred approach to reduce salt as it results in a clean label product, avoiding inclusion and declaration of chemical compounds. By careful reformulation using herbs and spices, the sensory characteristics and consumer acceptability of low salt products could be improved or maintained. However, studies in this area are limited. Mitchell, Brunton, and Wilkinson (2013) reported no significant difference in liking between a standard vegetable soup and a low salt soup with no herbs or low salt with rosemary, possibly due to the relatively small population size (n = 60). Furthermore, the standard and low salt soups contained 0.93% and 0.45% salt respectively, whereas current UK market soup products in 2013 were surveyed and found to have average salt content of 0.5%. The question, therefore, remains whether using herbs and spices is a useful tool for lowering salt content of commercial food products.

Preferences of food qualities are mostly caused by learned experience rather than genetics (Rozin & Vollmecke, 1986). Although food neophobia may cause reluctance to eat novel food (Pliner & Hobden, 1992), repeated exposure over time to the food stimulus may increase the familiarity and may alter taste perception and liking. Whilst repeated exposure to familiar foods may reduce the liking (Berlyne, 1970; Stang, 1975), novel foods are more likely to become more acceptable during the course of exposure (Birch & Marlin, 1982; Pliner, Pelchat, & Grabski, 1993; Stein, Nagai, Nakagawa, & Beauchamp, 2003). A novel stimulus causes an elevation in unfamiliarity, uncertainty or complexity of products, and hence an adverse initial effect on people who are food neophobic. The mechanism by which repeated exposure enhances the liking of novel foods can be explained as dissipation of initial food neophobia (Pliner, 1982).

In repeated exposure liking studies it is typical to make direct comparisons of two or more products at pre- and post-exposure tests but to only expose consumers to one product during the exposure period. This enables comparison of the effect of repeated exposure versus no exposure on liking ratings. Such metholodology was used by Methven, Langreney, and Prescott (2012) who hypothesised that reducing salt in a food may present a degree of novelty in an otherwise familiar food flavour which might be the cause of reduced liking and, therefore, repeated exposure may increase both familiarity and liking of the reduced salt food. In their study a carrot and coriander soup was used in which the salt content was reduced from 0.7% added salt to no added salt. This reduction led to a significantly lower liking pre-exposure. Liking of the no salt soup significantly increased over eight consecutive tasting sessions, until it was not significantly different from the standard salt soup. However, this study did not test the effect of the herbs on liking as both the standard and the low salt soup contained the coriander.

There is evidence that salt intake, salt taste sensitivity and liking of salty foods influence one another (Hayes, Sullivan, & Duffy, 2010). In their study a strong association was found between salt liking and measured sodium intake. Hence, it is perhaps important to consider dietary sodium intake in studies concerning salt liking and this was addressed in the current study.

The hypothesis of the current study was that the addition of herbs and spices can enhance the liking of low salt tomato soup. The first aim was to establish whether incorporation of herbs and spices into low salt tomato soup would give an immediate improvement in the hedonic liking. However, modifying the tomato soup's sensory profile by the reduction in salt content and addition of herbs and spices would create novelty in the flavour of tomato soup which may affect the participants' preference. The second aim was to repeatedly expose the participants to the tomato soup sample over 3 days and record the change in soup's acceptability, familiarity and consumed volume over exposure time. Finally, the third aim was to compare participant's liking of tomato soup pre- and post-repeated exposure to determine whether repeated exposure improved acceptability and familiarity of the low salt tomato soup with herbs and spices inclusion.

Materials and methods

Sample preparation

All soup samples were formulated and produced as an instant tomato soup powder by McCormick (Haddenham, UK). The aim was to set the salt (sodium chloride) content of the standard tomato soup at 0.5% (w/w) salt to represent the average salt level of UK commercial instant soup brands. Tomato soups with reduced salt levels (i.e. 30, 40, and 50% salt reduction) were produced for an initial consumer test to determine the low salt level to proceed into the main study. This was done to establish a lower salt level that the consumers liked significantly less than the standard soup level. In order to develop an herb and spice modified tomato soup that was acceptable to consumers, the formulation of the selected low salt sample was modified by inclusion of three different blends of herbs and spices as follows:

Basil modification: the low salt soup with added basil, black pepper, celery, and garlic.

Cumin and Coriander modification: the low salt soup with added cumin, coriander, ground celery seed and garlic.

Oregano modification: the low salt soup with added oregano, bay leaves, garlic, celery and black pepper.

For all tasting sessions, soup samples were prepared by suspending tomato soup powder in boiling water (11 g powder/100 mL water). The water used was potable tap water filtered through a cartridge (Brita, Bicester, UK) containing activated carbon to reduce odour and chlorine-derived compounds and ion-exchange resin beads to reduce levels of calcium carbonate. In the sip tests (i.e. sensory profiling, initial consumer trials and in the pre- and post-exposure studies), soup samples were prepared and held in a water bath at 70 °C before serving, serving temperature was 65 ± 3 °C. Each respondent received 30 mL soup in a china cup (50 mL). For the repeated exposure study (Visits 3–5), tomato soups were prepared and then held in thermos flasks for a maximum 15 min before serving, serving temperature was 69 ± 4 °C; each participant received a full portion (400 mL) of soup.

All experiments in the study were carried out in a central location using individual sensory booths. The booths were lit by artificial daylight and the temperature in the booths was controlled to 23 °C.

Selection of the low salt level samples

Four samples were tested in this experiment, the standard tomato soup (0.5% w/w salt content) and three different reduced salt samples (i.e. 30, 40 and 50% salt reduction). The consumers (n = 101) recruited to participate in this trial were students and staff at the University of Reading. Samples (30 mL) were presented monadically in a balanced order with three digit random codes and liking (overall liking followed by liking of appearance, taste and texture) was scored on a 9 point hedonic category scale (1: dislike extremely, 9: like extremely). They were asked to rinse their palates between samples with water and crackers (Carr's, UK).

Sensory profiling of the tomato soup variants

Five tomato soup variants were tested (i.e. standard, low salt, basil modification, cumin and coriander modification and oregano modification). A trained sensory panel (n = 10) developed a consensus vocabulary of 56 attributes over four tasting sessions. Scoring of all samples was carried out individually using 15 cm unstructured line scales (scaled 0–100). At each scoring session the standard sample

Table 1
Study design.

Visit	Visit 1	Visits on 5 consecutive days				
		Visit 2[a]	Visit 3[a]	Visit 4[a]	Visit 5[a]	Visit 6[a]
Pre-test to select H&S modification	Balanced monadic presentation: low salt samples with three different H&S modifications (30 mL)					
Pre-exposure test		Balanced monadic presentation: three samples (30 mL): standard, LS soup, oregano soup				
Repeated exposure, Visits 3–5 Control group Low salt group Herbs and Spices modification group			Single sample served, full portion of: standard, LS soup, oregano soup	Single sample served, full portion of: standard, LS soup, oregano soup	Single sample served, full portion of: standard, LS soup, oregano soup	
Post-exposure test						Balanced monadic presentation: three samples (30 mL): standard, LS soup, oregano soup

[a] Standard refers to the tomato soup with standard salt level, LS refers to the tomato soup with 50% lower salt, oregano refers to the tomato soup with 50% lower salt plus oregano, bay leaves, garlic, celery and black pepper.

was presented as a reference at the start of the session to re-familiarise the panel, along with the panel mean scores for the standard on a paper version of the line scales. The standard was then also presented as a blind coded sample; however, the panel were unaware of this. All samples were blinded with three digit random numbers and presented in balanced order. Samples were assessed in duplicate on two separate days.

Subjects in the main study

Subjects (160) were recruited via an external recruitment agent, with the aim of achieving a balance of gender, age ranges and socio-economic groups (Table 4). Exclusion criteria were: having surgery or a medical condition in the last 12 months affecting the taste or smell of food, diabetes, vegetarian, relevant food allergies and intolerances (e.g. herbs, spices, milk protein or lactose), prescribed medicine that is likely to affect food intake, taste, smell, appetite or behaviour. Participant drop out during the study was less than 10%. Participants did not receive any information about the aim of the study. Participants were asked to provide a full urine sample collected over 24 h (a full day excretion) for sodium analysis before the repeated exposure study. Sodium analysis of these samples was carried out as a marker of their daily salt intake. In addition, participants were asked to complete a food frequency questionnaire (FFQ) as another marker of their daily salt intake. A validated version of FFQ was obtained from the European Prospective Investigation into Cancer and Nutrition (EPIC) group. Data were analysed using FETA (FFQ software), a processing tool provided by EPIC. The project was given approval to proceed by the University of Reading Research Ethics Committee (study number: 13/09) and the volunteers gave their informed consent.

Sodium analysis

All soup samples provided by McCormick were analysed for sodium content. Sodium was extracted from 1 g of the tomato soup powder using deionised water (45 mL). After centrifugation, the pellet was re-extracted with further 45 mL water. Supernatants were combined, filtered, diluted (dilution factor [DF] 46) and analysed using atomic absorption spectrometry (AAS). Quantification was based on calibration curve of standard sodium (0–12 μg/mL). Extraction was done in triplicate.

To analyse sodium in urine samples, the volume of the 24 h urine collection was measured and a sample (15 mL) was centrifuged (1690 × g, 4 °C) and filtered (0.45 μm syringe filter). Portions (4 mL) of the filtrates were stored at −20 °C for later analysis. The urine samples were diluted (DF 500) and analysed using AAS, in triplicate. Quantification was based on calibration curve of standard sodium (0–14 μg/mL) and the resulting concentration of sodium was used to calculate the sodium content of the full 24 h urine sample. Participants were designated to have low, medium and high salt intake at <5, 5–10 and >10 g/day according to the histogram of the data.

Main study: acceptability of herb and spice blends followed by a repeated exposure study design

The main consumer study consisted of six visits (Table 1). In Visit 1, participants were asked to score the liking of three low salt samples reformulated using the three different herb and spice blends. The aim from Visit 1 was to determine the most liked herbs and spices modification to progress. After Visit 1, participants were divided into three groups, a Control group, a Low Salt group and the Herbs and Spices Modification (H&S Mod) group. Groups were balanced for gender, age, herbs and spices consumption (determined as self reported use of salt, pepper, herbs, spices and garlic in cooking), daily salt intake (from urine analysis) and their liking scores from Visit 1. Agglomerative hierarchical cluster analysis of consumer overall liking scores for the three herb and spice modifications from Visit 1 identified three clusters; the individuals in each cluster were evenly distributed throughout the three repeated exposure groups.

Consumers attended Visits 2–6 on 5 consecutive days at either 16:00 or 18:00 o'clock. On the pre- and post-exposure tests (i.e. Visits 2 and 6, respectively), three samples were presented monadically in a balanced presentation order to all participants with three digit random codes: standard soup, low salt soup and oregano modification soup. At these two visits liking (overall liking, liking of appearance, flavour, texture and aftertaste) and familiarity were scored on 15 cm unstructured lines (scaled 0–100), each anchored from "dislike extremely" to "like extremely". The consumers opinion of

the flavour intensity of each soup was also rated using a 5 point category just about right (JAR) scale, anchored from "much too weak" to "much too strong". Consumers were asked for free text comments on each sample. At Visit 6, consumers were additionally asked to rate their perceived intensity of salty, sweet and sour tastes on 15 cm unstructured lines (scaled 0–100). It was important to rate tastes other than just salt in order not to bias the consumers. The sample size served at Visits 2 and 6 was 30 mL, served in a grey china 50 mL cup (without a spoon). During Visits 3, 4 and 5 (repeated exposure phase), each participant was served just one soup, but a full portion (400 mL) of that soup in a grey china bowl (450 mL capacity) with a 15 mL stainless steel spoon. Participants in the Control group were served the standard soup, those in the Low Salt group were served the low salt soup and those in the H&S Mod group were served the oregano modification soup. During the exposure phase visits participants were asked to consume as much soup as they could or wanted to. They were asked to score their liking each day (overall liking, liking of appearance, flavour, and texture) and familiarity on 15 cm unstructured lines (scaled 0–100). For each participant, the quantity of soup consumed each day was weighed and recorded. Participants were asked to refrain from eating for at least 2 hours before all visits.

Directional paired comparisons for salt taste intensity

Two-alternative forced choice directional tests (2-AFC) were used to compare the low salt soup to the standard soup and the oregano modification soup to the standard soup, where the untrained assessors were asked to state which sample in the pair had the saltier taste. Sample presentation order was balanced within and between sample pairs and samples were coded with three digit random codes. Assessors were asked to rinse their palates between samples with water and crackers. The participants (n = 92) recruited in this test were students and staff at the University of Reading.

Statistical analysis

SENPAQ (version 3.2, UK) was used for two-way analysis of variance (ANOVA) and principal component analysis (PCA) of the sensory profiling data. Hedonic data were analysed using ANOVA, data were presented as means ± SE, $P < 0.05$ was considered significant. Multiple pairwise comparisons were done using Tukey HSD test. The pre-test liking data were analysed by two-way ANOVA with both sample and daily salt intake (low, medium, high) as treatment effects. For the comparison of the pre- and post-exposure data, paired sample t-tests (pre/post) were computed for each variant. For the repeated exposure ratings a repeated measures ANOVA (using an autoregressive error structure) was carried out to test both for overall differences between groups and between test days within the group but also a linear effect test was performed for all variants to determine whether the increase in liking was significant over the time of exposure. These analyses were all done using PROC MIXED in SAS® (version9.1.3 SAS Institute Inc). Agglomerative hierarchical cluster analysis was done in XLStat (version 2012.5.01, AddinSoft, France), and this was followed by ANOVA to determine any significant differences between the clusters. Data from the 2-AFC test for saltiness were analysed using DiffTest (version 2, 2002).

Results

Sodium analysis of soup samples

In the initial study to determine the low salt level to progress, the actual salt content of the standard soup was slightly lower than targeted (0.42% w/w rather than 0.5% w/w) and the percentage salt reductions were also slightly greater than their targets (32%, 0.29% w/w; 46%, 0.23% w/w and 57%, 0.18% w/w, respectively). The standard product manufactured for the herb and spice blends comparison was exactly as intended at 0.5% (w/w) salt. The three herb and spice modifications were slightly less in their salt reduction than targeted (43–45% rather than 50%). The standard product in the repeated exposure study was 0.57% (w/w) salt and the salt reduction of the low salt control and oregano modification were both 53% (0.26% w/w). The results of the sodium analysis are given in supplementary Table S1 in the online version at doi:10.1016/j.appet.2014.05.029.

Table 2
Consumer (n = 101) liking scores (9 point hedonic scale, mean ± SEM) of four tomato soup samples prepared with different salt content.

	Standard (0.42% salt content)	32% salt reduction	46% salt reduction	57% salt reduction
Overall liking	$6.6^{a} \pm 1.5$	$6.4^{ab} \pm 1.4$	$6.1^{ab} \pm 1.6$	$5.8^{b} \pm 1.6$
Liking of appearance	$6.6^{a} \pm 1.3$	$6.2^{ab} \pm 1.5$	$6.2^{ab} \pm 1.4$	$6.0^{b} \pm 1.5$
Liking of taste	$6.7^{a} \pm 1.6$	$6.3^{ab} \pm 1.6$	$6.0^{b} \pm 1.7$	$5.6^{b} \pm 1.8$
Liking of texture	$6.3^{a} \pm 1.7$	$6.2^{a} \pm 1.6$	$5.8^{ab} \pm 1.6$	$5.6^{b} \pm 1.8$

[a–c] Different superscripts in the same row indicate significant difference between means ($P < 0.05$).

Acceptability of soup at varied reduced salt levels

The aim of the initial consumer trial was to establish the reduction level in salt content that caused a significant decrease in the liking of tomato soup. Table 2 shows the hedonic ratings of the standard sample (0.42 g salt/100 g soup) as well as three different salt reduced samples (32, 46 and 57% salt reduction). The standard sample had the highest overall liking rating; however, the difference between the mean liking ratings was significant only with the 57% salt reduction sample ($F[3, 400] = 4.4$, $P = 0.005$). The liking of taste was significantly different between the standard sample and the 46% and 57% salt reduced samples ($F[3, 400] = 7.3$, $P < 0.0001$). Regarding the liking of appearance and texture, only the 57% salt reduction sample was scored significantly lower than the standard sample ($F[3, 400] = 2.6$, $P = 0.049$; $F[3, 400] = 4.2$, $P = 0.006$, respectively).

Sensory profiles of the tomato soup variants

Five tomato soup samples were sensory profiled; standard, low salt control and the three herb and spice modifications. Fifty-six attributes were evaluated, of which 28 were significantly different between samples ($P < 0.05$) (see supplementary Table S2 in the online version at doi:10.1016/j.appet.2014.05.029). The herb and spice variants were clearly distinguishable by their flavour profiles (basil, oregano, coriander and cumin odour and flavours). Regarding taste, although there was a significant difference in salty taste overall ($F[4, 36] = 2.7$, $P = 0.04$), the Tukey HSD test did not detect a significant difference between any pair of samples; however, the low salt control received the lowest means score for salt (22.8), whereas the basil and oregano modification scores (28.0 and 25.1, respectively) were closer to the standard (26.4). The oregano modification had a significantly more bitter taste than the standard soup (means of 15.4 versus 6.0; HSD = 4.8, $F[4, 36] = 9.14$, $P < 0.0001$) and bitter aftertaste (means of 14.8 versus 6.4; HSD = 3.8, $F[4, 36] = 11.72$, $P < 0.0001$). No significant difference in sweetness was found between samples ($F[4, 36] = 0.23$, $P = 0.9$). Inclusion of herbs and spices to tomato soups did not significantly affect the orange colour of tomato soup ($F[4, 36] = 1.23$, $P = 0.3$). The cumin and coriander modification had significantly lower tomato skin orthonasal odour compared with the standard (mean of 7.0 versus 14.7; HSD = 7.7, $F[4, 36] = 3.62$, $P = 0.014$).

However, as retronasal flavour, this difference was not significant. The herb and spice variants gave a more warming mouthfeel than the standard and low salt samples ($F[4, 36] = 13$, $P < 0.0001$). The basil and oregano modifications were significantly more astringent than the standard (means 10.8 and 11.5 respectively, compared with 6.6; HSD = 6.6, $F[4, 36] = 3.7$, $P = 0.013$). The after-effects of throat-catch and heat were evident in all herb and spice variants ($F[4, 36]$, $P = 0.008$; $F[4, 36] = 17.7$, $P < 0.0001$, respectively).

Acceptability of soups with varied herb and spice modifications

The low salt soup (43–45% salt reduction) flavoured with the three different blends of herbs and spices were tested in a consumer study (Visit 1) to determine the most liked variant to progress to the main study. However, there was no significant difference in the mean liking scores ($F[2, 447] = 0.37$, $P = 0.7$) (Table 3). In addition, no differences were found in the liking of flavour, texture, appearance and aftertaste, nor in the familiarity and the flavour intensity (Table 3).

However, a cluster analysis was used to determine whether the liking of samples was discriminated by different consumer groups. Hierarchical cluster analysis identified three clusters of consumers that had a relatively homogenous liking towards the samples (Table 3). The inferences from the cluster analysis were that in cluster 1 consumers did not like the oregano modification but preferred the other two variants. In cluster 2 consumers did not like the basil modification but preferred the coriander and cumin and the oregano modifications. In cluster 3 the consumers clearly liked the oregano modification and not the coriander and cumin. As the oregano modification had the highest mean liking score for any one particular cluster, did not have such a low liking score as the basil modification in any particular cluster, and had a higher rating for familiarity across the whole group than the cumin and coriander modification (although this was not significant), it was decided to progress the oregano modification to the repeated exposure study.

Table 3
Consumer liking (n = 150), familiarity and hedonic rating of the flavour intensity (Just about Right scale) (mean ± SEM) of three herb and spice variants of low salt tomato soup. Liking and familiarity rated on 100 point unstructured liking scales, just about right for flavour intensity rated using a 5 point category scale.

	Basil modification	Cumin and coriander modification	Oregano modification	Significance (P-value)
Overall liking	54.3 ± 2.1	55 ± 1.9	56.6 ± 1.9	0.69
Liking of appearance	59.6 ± 1.9	57.6 ± 1.8	56.9 ± 1.9	0.57
Liking of flavour	53.4 ± 2.1	53.2 ± 2.1	55.6 ± 2.0	0.66
Liking of texture	55.8 ± 2.0	55.8 ± 1.8	56.7 ± 2.0	0.93
Flavour intensity (JAR)	2.5 ± 0.1	2.61 ± 0.1	2.69 ± 0.1	0.24
Familiarity	54.7 ± 2.2	50.8 ± 2.2	55.8 ± 2.2	0.24
Liking of aftertaste	54.5 ± 1.9	51.2 ± 1.7	54.7 ± 1.7	0.28
Cluster* 1 (n = 56) mean overall liking	64.9[b]	57.7[b]	41.7[a]	<0.0001
Cluster 2 (n = 41) mean overall liking	36.0[a]	67.8[b]	57.8[b]	<0.0001
Cluster 3 (n = 53) mean overall liking	57.3[b]	42.2[a]	71.6[c]	<0.0001

[a–c] Different superscripts in the same row indicate significant difference between means ($P < 0.05$).

* The overall liking data were analysed by agglomerative hierarchical cluster analysis, three clusters were identified and the mean liking of the soup samples for each cluster are presented here.

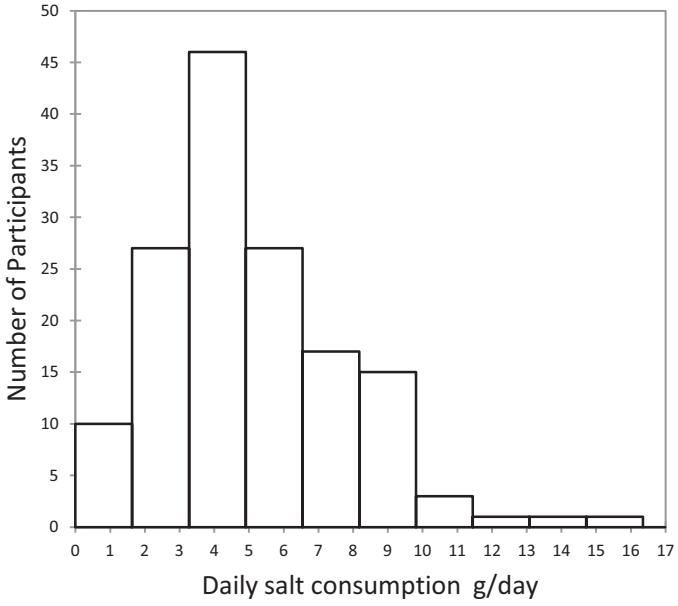

Fig. 1. Daily salt consumption (g/day) of the participants (n = 151) determined by measuring sodium in urine samples collected over 24 h.

Assessment of dietary sodium by urine analysis and food frequency questionnaire data

The aim of the 24-hour urine collection analysis was to estimate individual's 24-hour salt intake (g per day) in order to balance the consumer groups based on the daily salt consumption. Sodium analysis of the urine samples showed a wide range of daily salt consumption (0.9–15.3 g/day) among participants as shown in Fig. 1.

The mean daily salt intake of men (5.8 g/day) was significantly higher than the mean daily salt intake of women (4.5 g/day) ($F(1, 146) = 9.7$, $P = 0.002$). However, no significant difference was found between age groups. The mean daily salt intake across the group was 5.1 g/day and the median was 4.5 g/day. Similar to the urine analysis, FFQ analysis resulted in a wide range of recorded daily salt intake (1.1–15.9 g/day) (data not shown); however, the mean daily salt intake based on FFQ was 3.4 g/day and the median was 3 g/day.

Demographic data of the subjects in the main study

Table 4 shows the demographic data of total consumer cohort and within each exposure group. The exposure groups were balanced for gender, age, herbs and spices consumption, daily salt intake (from urine analysis) and their liking cluster from Visit 1 (Table 3).

Pre- and post-exposure

In the pre-exposure visit (Visit 2), consumer mean ratings of overall liking and liking of flavour were significantly higher for the standard soup ($F[2, 435] = 11.3$, $P < 0.0001$; $F[2, 435] = 11.0$, $P < 0.0001$, respectively) and no significant difference was found between the oregano modification and the low salt control soups (Table 5). Daily salt intake also had a significant effect on overall liking and liking of flavour ($F[2, 419] = 14.8$, $P < 0.0001$; $F[2, 419] = 11.4$, $P < 0.0001$, respectively), with liking for the soups increasing as daily salt intake increased. However there was no interaction between salt intake and sample and, hence, no indication that liking of high or low salt soups was effected by daily salt intake.

Ratings of familiarity showed a similar pattern to the overall liking, with both the low salt control and the oregano modifica-

Table 4
Demographic characterisations of all participants and participants within groups (all data represent the total number, n, in the category unless otherwise stated).

	Category	Total consumer cohort	Control group	Low salt group	H&S group
Volunteers		148	50	49	49
Gender	Male	69	24	22	23
	Female	79	26	27	26
Age (years)	35–40	32	13	8	11
	41–54	74	22	27	25
	55–60	42	15	14	13
	Age median (years)	48	48	46	48
Herbs and spices usage[a]	Low	29	8	12	9
	Medium	34	13	13	8
	High	81	27	24	30
Daily salt intake[b]	Low (<5 g/day)	87	29	29	29
	Medium (5–10 g/day)	56	19	19	18
	High (>10 g/day)	6	2	2	2
	Missing data	5	1	1	3
Liking clusters of herb and spice variants (Visit 1)[c]	1	56	19	19	18
	2	41	13	13	15
	3	53	17	18	18
Social economic group[d]	1–2	31	8	14	0
	3–5	74	27	23	24
	6–8	31	13	9	9
	No information	11	2	3	6
Nationality	British	126	44	44	38
	European	2	0	2	0
	Asian	1	0	0	1
	African	3	1	0	2
	Other	15	4	3	8

[a] Herb and spice usage groups determined as self reported use of salt, pepper, herbs, spices and garlic in cooking.
[b] Daily salt intake measured as sodium content of a urine sample collected over 24 h.
[c] Liking clusters of herb and spice variants tested in visit 1, as defined by agglomerative hierarchical cluster analysis.
[d] Socioeconomic groups declared according to the 2010 National Statistics Socio-economic Classification Guidelines (Rose & Pevalin, 2010).

tion being less familiar than the standard ($F[2, 435] = 5.5$, $P = 0.004$). The JAR score for flavour intensity of the low salt soup was significantly lower than for the standard and the oregano modification soups ($F[2, 435] = 24.9$, $P < 0.0001$), where the latter two samples were closer to "just about right" (an ideal value of 3 on the scale). More surprisingly, the low salt control was less liked for appearance and texture than the standard soup ($F[2, 435] = 4.2$, $P = 0.015$; $F[2, 435] = 4.8$, $P = 0.008$, respectively).

In the post-exposure visit (Visit 6), consumer ratings had the same trend as the pre-exposure visit with regard to the overall liking, liking of flavour and flavour intensity (Table 5). In addition, at Visit 6 the consumers were asked to rate their perception of the salty, sour and sweet tastes of the soups. Importantly, consumers found the oregano modification soup to be significantly saltier than the low salt control, despite matched sodium contents ($F[2, 432] = 4.1$, $P = 0.017$). However, they did not find the low salt control to be significantly less salty than the standard soup.

Comparing the pre- and the post-exposure ratings of the same soup across all volunteers (no grouping), there were no significant differences (data not shown). Analysis of consumer ratings within exposure groups, however, showed some significant differences between the pre- and post-exposure visits (see supplementary Table S3 in the online version at doi:10.1016/j.appet.2014.05.029). There was a trend in increasing overall liking of the oregano modification soup by the H&S Mod group ($t(46) = 1.75$, $P = 0.079$). Similarly, the low salt soup was liked more in the post-exposure visit by the low salt (LS) group which was exposed to low salt soup ($t(46) = 1.7$, $P = 0.09$). The liking of the standard soup was stable, there were no differences pre- to post-exposure rated by any group. Regarding the liking of flavour (Fig. 2), the H&S Mod group showed a significant increase for the oregano modification soup ($t(46) = 1.95$, $P = 0.05$). Likewise, the low salt soup flavour was liked significantly more in the post-exposure test by the low salt group ($t(46) = 2.2$, $P = 0.03$). However, no significant change in

Table 5
Consumer (n = 145) liking, familiarity, hedonic rating of flavour intensity (Just about Right scale) and the intensity of salty, sweet and sour tastes (mean ± SEM) of the soup variants in the per- and post-exposure visits. Liking, familiarity and the intensity of salty, sweet and sour tastes were rated on 100 point unstructured liking scales, and Just About Right for flavour intensity was done using a 5 point category scale.

	Pre-exposure			Post-exposure		
	Standard	Low salt control	Oregano modification	Standard	Low salt control	Oregano modification
Overall liking	$64.7^{a} \pm 1.9$	$52.5^{b} \pm 1.9$	$55.4^{b} \pm 1.9$	$65.0^{A} \pm 1.7$	$56.4^{B} \pm 1.9$	$56.4^{B} \pm 2.1$
Liking of appearance	$64.6^{a} \pm 1.7$	$57.6^{b} \pm 1.7$	$60.8^{ab} \pm 1.6$	$66.7^{A} \pm 1.5$	$61.1^{B} \pm 1.7$	$61.9^{AB} \pm 1.7$
Liking of flavour	$63.6^{a} \pm 2.0$	$50.6^{b} \pm 2.0$	$53.6^{b} \pm 2.2$	$64.0^{A} \pm 1.9$	$54.7^{B} \pm 2.1$	$56.5^{B} \pm 2.3$
Liking of texture	$63.3^{a} \pm 1.9$	$55.1^{b} \pm 1.9$	$58.6^{ab} \pm 1.8$	$64.3^{A} \pm 1.8$	$56.9^{B} \pm 1.9$	$58.7^{AB} \pm 1.9$
Familiarity of flavour	$61.6^{a} \pm 2.0$	$54.5^{b} \pm 2.1$	$52.2^{b} \pm 2.2$	$63.3^{A} \pm 1.8$	$57.1^{AB} \pm 2.1$	$55.0^{B} \pm 2.2$
Flavour intensity (JAR)	$2.7^{b} \pm 0.1$	$2.3^{c} \pm 0.1$	$2.9^{a} \pm 0.1$	$2.7^{B} \pm 0.1$	$2.5^{C} \pm 0.1$	$3.0^{A} \pm 0.1$
Liking of aftertaste	$61.2^{a} \pm 1.8$	$50.7^{b} \pm 1.8$	$50.5^{b} \pm 2.1$	$60.5^{A} \pm 1.7$	$54.8^{AB} \pm 1.8$	$51.4^{B} \pm 2.2$
Sweet taste intensity	–	–	–	$50.5^{A} \pm 1.6$	$50.5^{A} \pm 1.8$	$46.7^{A} \pm 1.8$
Salty taste intensity	–	–	–	$38.5^{AB} \pm 1.8$	$33.7^{B} \pm 1.5$	$40.3^{A} \pm 1.7$
Sour taste intensity	–	–	–	$31.6^{B} \pm 1.8$	$32.8^{AB} \pm 1.9$	$38.5^{A} \pm 1.9$

[a–c] Different superscript lowercase letters in the same row indicate significant difference between means at $P < 0.05$ (pre-exposure).
[A–C] Different superscript capital letters in the same row indicate significant difference between means at $P < 0.05$ (post-exposure).

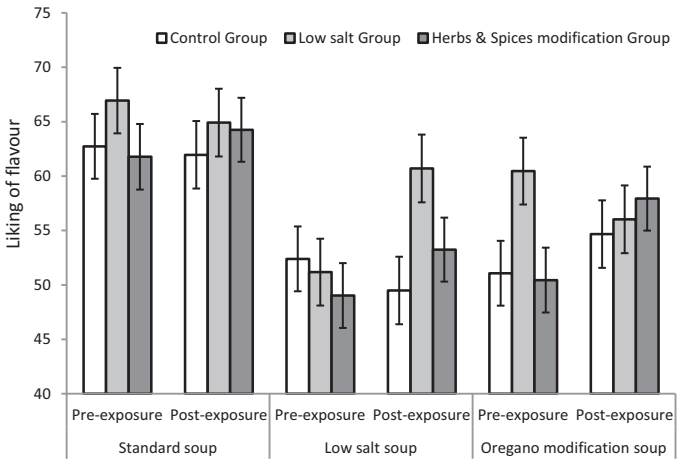

Fig. 2. Pre- and post-exposure ratings (mean values, error bars represent SEM) of liking of flavour by Control, Low Salt and H&S Mod groups for standard, low salt control and oregano modification soups.

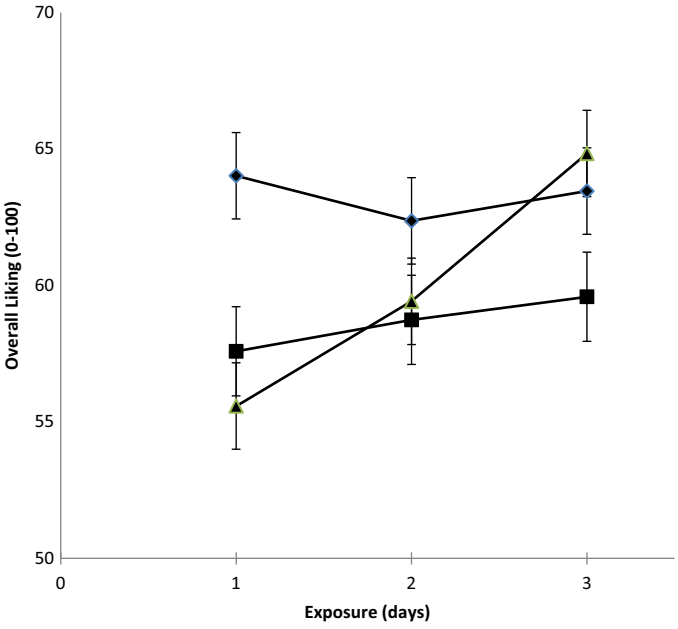

Fig. 3. Overall liking development across the repeated exposure days (error bars represent SEM). ■ = low salt soup; ▲ = oregano modification soup; ◆ = standard soup.

rating of the standard soup by the control group was observed ($t(46) = -0.2$, $P = 0.8$). Surprisingly, the H&S Mod group did not have a significant increase in the familiarity for the oregano modification ($t(46) = 1.32$, $P = 0.18$), whilst the low salt soup had a significant increase in the familiarity by the LS group ($t(46) = 3.15$, $P = 0.002$).

Repeated exposure test

Each group of participants (Control group, LS group or H&S Mod group) was exposed to a full portion of the same tomato soup for 3 consecutive days. Different trends were observed during the exposure course for each group. Table 6 shows the change in the hedonic and familiarity ratings in all groups during the time frame of exposure.

Over the exposure period the overall liking of the standard soup and the low salt soup remained stable whereas the liking of the oregano modification soup increased over the 3 day exposure as shown in Fig. 3 ($t(285) = 2.34$, $P = 0.02$).

Repeated exposure to the oregano modification soup led to a similar significant linear increase in liking of flavour ($t(285) = 2.3$, $P = 0.02$), liking of texture ($t(285) = 2.55$, $P = 0.01$) and in familiarity ($t(285) = 3.1$, $P = 0.002$) over the exposure time (Table 6).

The consumed quantities of the soups were recorded over the exposure course; however, no significant changes were observed in any of the tested soups. The average consumed volumes were 271, 260 and 237 mL for the standard, low salt and oregano modification soups, respectively, with no significant difference between the groups (data not shown). Of the free comments collected at Visits 2–6, few related to salty taste and there were no clear trends. At the pre-exposure visit (Visit 2), of 150 consumers only 15 consumers commented on salty taste; three reported it to be right, whereas seven stated it to be too low and five said it was too high, and there was no trend in which samples these comments were assigned to. During the exposure period, of 432 possible comments only 20 comments related to salt and again there were no clear trends. At the post-exposure visit there were 37 comments on salty taste; concerning the standard product there was a higher proportion of the comments (10 out of 16) stating that it tasted too salty, whereas seven out of 10 comments reported the oregano variant to be too low in salt.

Table 6
The change in liking and familiarity ratings during repeated exposure time by Control (n = 49), Low Salt (n = 47) and H&S Mod (n = 49) groups.

	Exposure group[a]	Visit 3	Visit 5	Visit 5–Visit3	Significance of linear effect (P value)
Overall liking	Control	64.0 ± 3.1	63.5 ± 3.4	−0.6	0.89
	Low salt	57.6 ± 3.2	59.6 ± 3.7	+2	0.62
	H&S Mod	55.6 ± 3.4	64.8 ± 2.9	+9.0	0.02
Liking of flavour	Control	62.6 ± 3.3	62.6 ± 3.8	0.0	0.99
	Low salt	56.0 ± 3.3	58.8 ± 3.4	+2.8	0.53
	H&S Mod	53.2 ± 3.4	62.9 ± 3.1	+9.8	0.02
Liking of texture	Control	55.6 ± 3.4	58.3 ± 3.7	3.2	0.43
	Low salt	52.0 ± 3.3	59.4 ± 3.4	7.5	0.07
	H&S Mod	54.2 ± 3	64.3 ± 3.1	10.1	0.01
Liking of appearance	Control	62.6 ± 3.1	62.6 ± 3.6	2.7	0.42
	Low salt	56.0 ± 2.8	58.8 ± 3.4	+7.1	0.04
	H&S	53.2 ± 2.7	62.9 ± 3	+4.4	0.19
Familiarity	Control	59.3 ± 3.5	64.4 ± 3.3	+5.1	0.19
	Low salt	53.2 ± 3.1	57.7 ± 3.4	+4.5	0.25
	H&S Mod	54.1 ± 3.8	66.0 ± 3.3	+11.9	0.002

[a] H&S Mod denotes the group exposed to the herb and spice modification (the oregano soup) over the 3 day exposure period.

Directional paired comparisons of perceived saltiness

The 2-AFC test showed that low salt sample was perceived to be significantly less salty than the standard one ($P < 0.0001$), 63 out of 92 consumers scored the standard sample as saltier. However, no significant difference in saltiness was observed between the standard and the oregano modification samples ($P = 0.23$), only 50 out of 92 consumers scored the standard sample as saltier. It was reasonable to accept that the samples led to statistically the same perception of salt taste intensity because the best estimate for the proportion of discriminators was low at 8.7% (with an upper boundary of 29.5% at $P < 0.05$).

Discussion

Selection of sodium reduction level and the herb and spice seasoning

In agreement with the literature (Liem et al., 2011), decreasing salt content caused a loss in palatability and consumer acceptance. Since 57% salt reduction was required to achieve a significant decline in overall liking compared with the standard sample, it was chosen as the level on which to test the hypothesis that flavouring by herbs and spices would improve consumer acceptance. The significantly lower liking of appearance, taste and texture of the 57% salt reduction sample compared with the standard indicates the important role of salt in overall sensory quality (Doyle & Glass, 2010). However, it should also be considered that once consumers have scored their overall liking of the product they may tend to reflect this impression of liking onto their liking of specific modalities. In this case the sensory profiling of the soups found no significant differences between the standard and low salt control soups for any appearance or mouthfeel attribute; hence, true differences in liking of appearance and texture are unexpected.

Sensory profiling of the tomato soup variants

Importantly, this part of the study demonstrated that salty taste of low salt soup can be compensated by reformulation of the sensory profile. The basil and oregano modifications were not perceptually less salty than the standard soup (see supplementary Table S2 in the online version at doi:10.1016/j.appet.2014.05.029). However, the low salt control, although rated lower in salty taste than the standard, was not significantly different. Similarly in the consumer study, participants found the oregano modification to be significantly more salty than the low salt control and not different from the standard, although the low salt control was also not rated significantly different in salty taste to the standard (Table 5). However, directional forced choice tests are more sensitive than unstructured line scale ratings and the 2-AFC did find the low salt control to be significantly less salty than the standard, whereas the oregano modification was not different to the standard. This proves the capability of the herbs and spices used in the study to compensate the salty taste in the low salt soup. One probable cause of the enhanced salty perception conveyed by the oregano herb blend is cross-modal enhancement of salty taste perception by the volatile aroma compounds. Previous studies have found congruent flavours, both complex savoury flavourings as well as single flavour compounds, to enhance salty taste (Batenburg & van der Velden, 2011).

The herb and spice modifications, as expected, contributed their specific odour and flavour notes such as basil, cumin, coriander and pepper notes. However, the addition of oregano caused a significant increase in bitterness and astringency; which may be undesirable to some consumers. The amount of herbs and spices added to soup must be carefully assessed to avoid intense flavour generation that might detract from the main flavour of the soup, in this case tomato. In this study the tomato flavour was maintained in all samples.

Daily salt consumption of study volunteers

The average daily salt intake (calculated by urinary sodium) of participants (5.1 g/day) was considerably less than the reported average salt intake of the English population (8.1 g/ day) (Department of Health, 2011) and less than the recommended maximum daily amount of 6 g (Food Standards Agency, 2009). The low calculated salt intake may reflect the demographics of the recruited participants being from the South East England with low participation of lower socio-economic groups (Table 4). Salt intake estimated by FFQ was lower and did not correlate with the results of urine analysis (data not shown); such underestimation of salt intake from FFQs has been reported in previous studies (Hayes et al., 2010). Therefore, only urine salt results were considered when grouping participants. In the pre-exposure liking test it was found that the liking of the soups was significantly effect by daily salt intake, with participants in the higher intake groups liking the soups more. It was therefore concluded that using salt intake as one of the factors to balance the participant groups for the exposure study was valid. However daily salt intake did not affect liking for the salt level in the soup.

Preference development from pre- to post-repeated exposure

In this study, the first objective was to investigate whether selected herbs and spices could enhance saltiness perception and increase the liking of low salt tomato soup. Pre-exposure, reducing the salt content caused a significant decrease in the familiarity and overall liking of tomato soup and reduced the acceptability of the flavour intensity to below "Just about Right" (Table 5). When modified with oregano, the liking and familiarity remained significantly lower but the acceptability of the flavour intensity (JAR) was not affected. Herbs and spices should be chosen carefully to complement the foods rather than creating a contrast in flavours. For example, although the consumers exposed to the oregano modified soup (H&S Mod group) did increase their liking of the flavour of the soup significantly over the repeated exposure period (Fig. 2), the soup was more bitter (determined by sensory profiling) which may have contrasted with the expected tomato flavour. In a previous study where herbs and spices were added to reduced salt vegetable soup (Mitchell et al., 2013), the use of a blend of rosemary, oregano and sage lowered consumer acceptability below that of the standard salt soup, whereas the modification which incorporated rosemary was not significantly different. In agreement with the current study, this finding implies that the complementary nature and overall intensity of the herb and spice addition is essential to the success of the strategy.

Food neophobia is defined as a person's reluctance to consume either novel or unusual foods (Pliner & Hobden, 1992). Reformulating the tomato soups modified the sensory profile, resulting in a less familiar product. Previous studies show that repeated exposure to an initially novel food can reduce food neophobia and increase liking (Birch & Marlin, 1982; Sullivan & Birch, 1990; Wardle, Herrera, Cooke, & Gibson, 2003), whereas preferences to normal food may decline or remain stable with repeated exposure (Berlyne, 1970; Siegel & Pilgrim, 1958; Stang, 1975). The results of the current study are supported by these theories. The group exposed to the novel product (the H&S modified soup) demonstrated a significant increase in overall liking for the oregano modification soup over the 3 exposure days. However for the groups exposed to the normal foods, the standard and the low salt soups, liking remained stable over the exposure days. The steady increase in overall liking of the oregano modified soup is consistent with the optimal arousal theory

(Dember & Earl, 1957). Reducing salt content and incorporating herbs and spices into typical tomato soup generated a novel stimulus; it led to an increase in complexity of the flavour profile and increased unfamiliarity and hence an initial decline in liking compared with the standard. The complexity and unfamiliarity decreased over repeated exposure and hence an increase in the liking, and familiarity occurred. On the other hand, repeated exposure to stimuli that are initially perceived as optimal, the standard soup in this case, did not lead to major changes in liking, as expected by the optimal arousal theory. Due to the important role of salt on the sensory characteristics of foods, Methven et al. (2012) hypothesised that as a significant decrease in salt content would change a sensory profile, it could be considered as a novel change to the flavour of the food. This previous study of a no added salt soup found a significant increase in liking over exposure, without additional herbs or spices; although fresh coriander was added to all soups. This observation contrasts with the current study which achieved only a limited increase in liking of the low salt control soup over exposure, but the former study had a longer exposure time (8 days versus 3 days).

Zajonc (1968) stressed the positive link between liking and familiarity in repeated exposure studies. Other theories stress the necessity of specific stimulus characteristics such as complexity to cause preference development over repeated exposure (Berlyne, 1970; Dember & Earl, 1957). However, most theories agree that with repeated exposure novelty dissipates and familiarity increases. In the present study, the increase in familiarity of the oregano modified soup was evident during the exposure course, whilst a limited development in the familiarity for the standard and low salt soups occurred. This finding highlighted the positive effect that familiarity can have on liking.

Consumed volume of tomato soup was measured at each exposure to ensure compliance and to determine whether the increase in liking and familiarity of the flavoured soup would be accompanied by an increase in the consumed volume. Studies show that repeated exposure to the same food for several days can decrease the intake of that food, even if the food was initially liked (Zandstra, de Graaf, & van Trijp, 2000). In the current study, the consumption of the standard soup might be expected to decline as a result of a boredom effect (Walker, 1980; Zandstra et al., 2000), whilst intake of the H&S modified soup may be expected to increase as the liking and familiarity increased over exposure time. However, no significant changes were observed during the exposure time frame for either soup. This result could be due to the short exposure course followed in this study. Additionally, the soup was served unaccompanied as a main course, with no bread, which is not common practise for most consumers.

Conclusion

In this study, as a tool to compensate saltiness and increase consumer preference, the inclusion of herbs and spices to low salt tomato soup was evaluated. The results show that reducing salt in tomato soup led to an immediate decline in consumer liking and that incorporating herbs and spices was not able to cause an instant enhancement of liking. However, the herb and spice blends used in this study were capable of enhancing the perception of salty taste and compensating for a 53% reduction in added salt. In agreement with the psychological literature, this study found that initial liking was not static, but developed over repeated exposure. Repeated exposure to the reduced salt tomato soup modified with the addition of oregano, bay leaves, garlic and black pepper led to a significant enhancement in the overall liking and liking of flavour, texture and aftertaste, whereas no changes were observed for the standard and low salt tomato soups during the repeated exposure phase. Although there was a positive trend in increasing the liking of the developed tomato soup between pre- and post-exposure, where it was compared directly with the standard salt soup, this was not significant. It remains to be determined whether such a change post exposure would be significant following a longer exposure period or across a larger consumer group. The current findings should encourage manufacturers to reduce salt in certain food products by the addition of carefully selected herbs and spices.

Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.appet.2014.05.029.

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