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Impact of salt reduction on the instrumental and sensory flavor profile of vegetable soup

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ABSTRACT

The flavor of two vegetable soups, a commercial regular salt soup (0.93% NaCl) and its reformulated low salt equivalent (0.45% NaCl), were profiled using flavor profile analysis and solid-phase microextraction (SPME) coupled with gas chromatography mass spectrometry (GC–MS) instrumental analysis. Generalized procrustes analysis (GPA) of the sensory data revealed that the regular salt soup was strongly correlated with the attributes "salt flavor", "yellow color", "carrot aroma" and "overall flavor". Reducing the salt content of the low salt soup had a significant effect on the attributes "green color", "sweet flavor" and "pepper flavor". SPME–GC–MS analysis revealed high concentrations of terpenes and thioethers in the headspace of the soups. A "salting-out" effect was observed in the regular salt soup with significantly higher concentrations of limonene, *p*-cymene, β-caryophyllene and isopropyl disulfide identified, however, exceptions were observed in the form of dimethyl sulfide and α-patchoulene, both of which were more abundant in the low salt soup. Partial least squares regression (PLSR) identified significant positive relationships between the volatile compounds propanol-1, hexanal, limonene, *p*-cymeme, isopropyl disulfide and β-caryophyllene and the sensory attributes "salt flavor", "yellow color", "carrot aroma", "overall flavor", "overall flavor complexity" and "aftertaste", all of which were found to be related to the regular salt soup.

1. Introduction

The rationales behind consumer food purchasing choices are many and varied; however, undoubtedly one of the most important motives in terms of repurchasing is whether a food product tastes good. Concurrent with the demand today for food products that are tasty and convenient, is the additional requirement that these products contain reduced levels of sugar, fat and salt (sodium chloride). Consequently, there is pressure on manufacturers to achieve these goals without impacting on the original taste and flavor of the product. In addition, with the evidence relating high sodium consumption to high blood pressure steadily increasing (FSAI Scientific Committee, 2005; Intersalt Cooperative Research Group, 1988; Law, 1997), health organizations worldwide have called for a reduction in the average sodium intake of the general population, through a reduction of the sodium chloride content in processed foods (World Health Organization, 2003). Processed foods, including soups, ready-meals and comminuted meat products, are a leading contributor to salt intake worldwide. However, the salt in these foods performs a number of important technological functions, ranging from preservation to increased processibility. One of the most important roles of salt lies in its ability to impart distinctive taste properties, including the enhancement and/or modification of the flavor and tastes of other ingredients within a food (Durack, Alonso-Gomez, & Wilkinson, 2008; Hutton, 2002). Therefore, by reducing the amount of salt added to processed foods, both the perception of saltiness and the taste intensity of other flavors can be altered, resulting in a product whose taste and flavor may be inferior to that of the original salted product.

Flavor perception is a dynamic process and one which must engage the consumer, in addition to the chemistry and physics of the food (Piggott, 2000). Flavor is a highly complex system and consists largely of three components—taste, aroma and texture. The overall flavor of a food is largely a function of aroma; the sensations perceived by the olfactory system when volatile substances are released from foods or beverages; which in turn arise as a result of characteristic tastes and flavors present in the food (Coultate, 1999; Noble, 1996). The perception of aroma is dependent upon the concentration and odor threshold of the volatile compounds present in a food (Guichard, 2002; Pérez-Juan, Flores, & Toldrá, 2007). Flavorsome foods can often contain hundreds of volatile compounds; however, within a food these volatiles commonly interact with macronutrients such as proteins, fats and carbohydrates, which can result in their uneven release from the food (Chung, Heymann, & Grün, 2003). The perception of flavor and aroma volatiles is further influenced by their solubility, which subsequently can be affected by the level of salt

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present in a food. The addition of salt to foodstuffs results in reduced water activity (a_w) due to the formation of strong ion–dipole interactions between the salt ions and water (Rabe, Krings, & Berger, 2003); this results in the decreased availability of water molecules for the solubilization of flavor compounds. This phenomenon known as the "salting-out" effect, results in an increased flavor release from food due to the decreased availability of water molecules for the solubilization of flavor compounds (Flores, Gianelli, Pérez-Juan, & Toldrá, 2007; Rabe et al., 2003).

Many food manufacturers now use complex statistical analyses in order to achieve the best product formulation in relation to sensory acceptability, shelf life, nutritional demands and physiochemical stability (Granato, Branco, & de Araújo Calado, 2011). Generalized procrustes analysis (GPA) is a technique in which data generated by each panel member is analyzed separately, correcting for individual differences in the use of the line-scale and in the interpretation of the sensory attributes (Byrne, O'Sullivan, Dijksterhuis, Bredie, & Martens, 2001; Grower, 1975). Although this process of analysis is commonly associated with the Free Choice Profiling (FCP) method, it is practical in the analysis of conventional profiling data as despite extensive training individual differences between panelists can still exist (Dijksterhuis, 1995). GPA generates a consensus plot that matches the configuration of the data sets by centering, rotating and adjusting scales of each data set (Chung et al., 2003). Thus, the three major elements, samples, panelists and sensory attributes, can be examined and contrasted using a single encompassing analysis (de Jong, Heidema, & van der Knaap, 1997). Partial least squares regression (PLSR) is frequently used to understand the relationships between instrumental (X) and sensory (Y) data sets by predicting one data set from the other (Martens & Martens, 2001). PLSR provides solutions to both X and Y variables and simultaneously investigates the relationship between instrumental volatile compounds and sensory attributes.

Despite the downward pressure on salt levels, there is still very little published information on the impact salt reduction may have on the sensory characteristics and volatile composition of complex processed food systems such as soup products. This information could potentially be used in the reformulation of these products without adversely affecting the sensory and flavor profiles. In particular, very few studies have attempted to assess the impact of reducing salt on flavor perception by both sensory and instrumental methods on a commercial product and its reformulated lower salt counterpart. The current study aims to address this issue by firstly conducting descriptive flavor profiling to determine the effect of salt reduction on the sensory properties of a popular commercial vegetable soup ready-meal and secondly, by conducting flavor volatile analysis to determine whether the "salting out" phenomenon had an effect on the volatile profile of a complex food system such as a soup.

2. Materials and methods

2.1. Ready-meal samples

A popular commercially available freeze-chilled vegetable soup was selected for study. Two separate 500 kg batches of vegetable soup were manufactured by Dawn Fresh Foods Ltd., Fethard, Co. Tipperary, Ireland, according to their standard industrial protocol, a list of ingredients used are listed in Table 1. One batch contained regular commercial levels of sodium whereas the second batch was reformulated to contain significantly reduced sodium levels (Table 2). Samples were pre-packaged in approximately 250 g portions and stored at −18 °C upon receipt.

Table 1
Ingredient declaration for vegetable soup.[a]

Vegetable soup ingredient list	
1. Water	9. Milk
2. Vegetable stock	10. Vegetable bouillon
3. Carrots	11. Salt
4. Potato	12. Cream
5. Turnip	13. Vegetable oil
6. Onions	14. Parsley
7. Celery	15. Ground white pepper
8. Butter	

1–15 = Abundance of each ingredient from most abundant (1) to least abundant (15).
[a] Exact compositional make-up cannot be disclosed due to confidentially.

2.2. Sample preparation—sensory profiling

Two-three days prior to sensory evaluation the required number of regular and reduced salt soups were removed from the freezer and tempered to chill at 4 °C. On each day of testing, meals were removed from chilled storage and individually cooked for approximately 7 min on full power in a microwave oven (850 W) and subsequently distributed evenly in approximately 35 g portions into circular foil cases (50 mm diameter). Samples were served to panelists at approximately 72 °C.

2.3. Sensory profiling analysis

Sensory profiling analysis (flavor profile method) was conducted on the regular and low salt versions of the soup according to the guidelines set out in the international standards ISO 6658: 2005(E) and ISO 6564: 1985(E) (alternatively see Meilgaard, Civille, & Carr, 1991). The method was selected to determine the major flavors and aromas present in the commercial regular salt soup and to establish the effect that reducing salt had on the intensity of these flavors. The panel which consisted of eight members, 6 male and 2 females in their twenties and thirties, were selected and trained according to the guidelines set out in ISO 8586–1: 1993(E) and in ISO 6564: 1985(E). The panelists' were selected from staff and students of the Teagasc Food Research Centre, Ashtown, Dublin, all of whom had previous sensory experience. Screening using a series of acuity and discrimination tests (ISO 8586–1: 1993(E)) was conducted and panelists were required to correctly complete all sessions to be eligible for inclusion in the study. The selected panel members were trained over a period of six 1.5–2 h sessions. A set of descriptors were developed and defined for the soups during training, which covered the appearance, flavor and aroma attributes of the soups, their order of perception and intensity. A total of 12 descriptors were developed and agreed upon by panel consensus (Table 3). Sensory profiling was carried out on separate days and all evaluations were carried out at the same time each day, in a sensory laboratory which included individual testing booths equipped with serving windows and controlled lighting. All samples were individually presented to panelists in a random order on white paper plates labeled with random three digit codes. The panelists were presented with a total of 2 samples per session. A randomized balanced sample presentation order was used for intensity scaling to minimize bias due to first-order and carry-over effects (Baxter, Easton, Schneebeli, & Whitfield, 2005; MacFie, Bratchell, Greenhoff, & Vallis, 1989) which resulted in a total of 4 replications being conducted on the meals (one presentation of each of AB, AA, BA and BB). Intensity ratings for each of the descriptive terms were scored

Table 2
Sodium content and salt equivalents for regular and low salt vegetable soup.

	Regular salt soup		Low salt soup	
	Sodium[a] (g/100 g)	Salt equivalent[b] (g/100 g)	Sodium[a] (g/100 g)	Salt equivalent[b] g/100 g
Vegetable soup	0.37	0.93	0.18	0.45

[a] Sodium content determined using atomic absorption spectrophotometer (Mitchell et al., 2009).
[b] Salt equivalent determined by multiplying sodium content by 2.5.