INDIVIDUAL DIFFERENCES IN THE SENSORY PERCEPTION OF FATS

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Excessive consumption of dietary fat is acknowledged to be a widespread problem linked to a range of medical conditions. Despite this, little is known about the specific sensory appeal held by fats and no previous published research exists concerning human perception of non-textural taste qualities in fats. This research aimed to address whether a taste component can be found in sensory perception of pure fats. It also examined whether individual differences existed in human taste responses to fat, using both aggregated data analysis methods and multidimensional scaling. Results indicated that individuals were able to detect both the primary taste qualities of sweet, salty, sour and bitter in pure processed oils and reliably ascribe their own individually-generated taste labels, suggesting that a taste component may be present in human responses to fat. Individual variation appeared to exist, both in the perception of given taste qualities and in perceived intensity and preferences. A number of factors were examined in relation to such individual differences in taste perception, including age, gender, genetic sensitivity to 6-*n*-propylthiouracil, body mass, dietary preferences and intake, dieting behaviours and restraint. Results revealed that, to varying extents, gender, age, sensitivity to 6-*n*-propylthiouracil, dietary preferences, habitual dietary intake and restraint all appeared to be related to individual variation in taste responses to fat. However, in general, these differences appeared to exist in the form of differing preferences and levels of intensity with which taste qualities detected in fat were perceived, as opposed to the perception of specific taste qualities being associated with given traits or states. Equally, each of these factors appeared to exert only a limited influence upon variation in sensory responses and thus the potential for using to taste responses to fats as a marker for issues such as over-consumption, obesity or eating disorder is at present limited.

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Overview of the sensory perception of taste

Taste and smell are the two senses most involved in the processes of eating and drinking (Logue 1991). Both are "chemical senses" which frequently interact with each other and operate by detecting molecules of chemical substances (Goldstein 1996). The process of taste, or gustation as it is also known, begins on the surface of the tongue, which is covered with a variety of structures called papillae (Goldstein 1996; Bartoshuk 1993). Four different kinds of papillae are located on the human tongue. Filiform papillae are the most numerous and they resemble small points and are distributed throughout the surface of the tongue. Foliate papillae, which form a series of "folds," are located predominantly on the rear edges of the tongue. Circumvallate papillae are large circular structures found on the back of the tongue and fungiform papillae have the appearance of small mushroom-like structures and are distributed most densely at the tip and edges of the tongue (Bartoshuk 1993; Logue 1991). All papillae, with the exception of filiform papillae, contain taste buds (Goldstein 1996). Therefore stimulation of the central part of the tongue which contains only filiform papillae causes no taste sensations. Taste receptors are also scattered throughout other parts of the oral cavity, such as the soft palate of the roof of the mouth (Coren and Ward 1989).

The whole human tongue is estimated to contain approximately 10,000 taste buds (Goldstein 1996). Taste buds are made up of clusters of taste receptor cells which communicate with the surface of the papilla in which they are embedded via their tips which protrude into a small opening known as the taste pore (Bartoshuk 1993; Goldstein 1996). Within each taste bud the individual taste cells are constantly evolving and developing, with each cell having an expected life-span of a few days. Therefore, the composition of taste buds is continually changing, with immature, mature and dying cells always present (Coren and Ward 1989).

When chemical stimuli make contact with the receptor sites on the tips of taste cells a process known as transduction occurs. This involves substances affecting the ion flow across the membrane of the taste cells, thus also affecting the cells' electrical charge (Goldstein 1996). This mechanism leads to the release of neurotransmitters across the synapse of the receptor cell and the taste nerve, causing spike potentials to travel up the taste nerves (Coren and Ward 1986).

Each side of the tongue is innervated by three large cranial nerves; VII, IX and V. These are responsible from carrying fibres from the taste buds. Classical taste literature suggests that the chorda tympani (a branch of the VIIth cranial nerve) carries taste sensations from the fungiform papillae on the anterior two thirds of the tongue, the trigeminal nerve (Vth Cranial nerve) carries thermal, touch and pain sensations from the anterior two thirds of the tongue and the glossopharyngeal nerve (IXth cranial nerve) carries taste, thermal, touch and pain sensations from the foliate and circumvallate papillae on the posterior one third of the tongue (Catalanotto et al 1991; Bartoshuk 1993). Fibres in the above three nerves synapse in the brain stem in the nucleus of the solitary tract, located in the medulla (Goldstein 1996). From there, taste information is carried via a set of pathways called medial lemniscus to the taste centre of the thalamus. The thalamic taste area projects to three areas of the brain; the anterior insular cortex and two regions at the base of the primary insular cortex (Coren and Ward 1989; Bartoshuk 1993).

The precise nature of neural coding for specific taste qualities remains in question at present, however two major theories have emerged, both of which could be used to explain data collected from both animal and human studies (Goldstein 1996). The "across-fibre pattern" theory suggests that taste quality is signalled by a pattern of neural activity in which various neural units have different stimulus-specific response rates (Coren and Ward 1989; Goldstein 1996). By contrast, the specificity, or "labelled-line" theory suggests that taste quality is signalled by the firing of neurons in taste fibres tuned to respond to a single basic taste quality (Coren and Ward 1989; Goldstein 1996).

How do individuals perceive dietary fat?

Dietary fat plays a vital role in maintaining the health of the human body (Lichtenstein et al 1998) and, alongside carbohydrates and protein, is one of the three major components of food (Anon 1981). Fat acts as a concentrated source of energy, it is a carrier of fat-soluble vitamins and facilitates their absorption and certain fatty acids are also defined as essential since the human body is unable to synthesise them in adequate quantities (Lichtenstein et al 1998). In addition to this, fat is also a major texture and flavour component of food and is crucial in influencing diet palatability (Drewnowski 1995) by making food flavourful, varied and rich (Cooper 1987).

However, excessive dietary fat consumption has also been implicated as a contributory factor in a number of major chronic diseases, including cardiovascular diseases, various cancers and diabetes (Danforth 1985; Surgeon Generals Report 1988; National Academy of Sciences 1989; Lichtenstein et al 1998). It is also regarded as a primary cause of obesity (Danforth 1985; National Academy of Sciences 1989; Lichtenstein et al 1998) which, in itself, is linked to a wide range of medical problems and conditions (Black et al 1983; Lichtenstein et al 1998; Stern 1999). Despite widespread attempts to inform people in modern western society about such risks however, even the best educated of consumers remain largely resistant to a diet which involves reducing their fat intake to the recommended level of below 30% (Drewnowski 1990). In fact, it has been estimated that, on average, individuals still consume 37-42% of their food energy as fat (Mela 1995).

Whilst extensive literature exists demonstrating the potential physiological effects of excessive fat consumption, little is known about why humans select and ingest fat at levels well above those of physiological need (Mela 1990). It has been argued that people may not possess the knowledge to accurately conceive their own fat intake (Brug et al 1999; Sparks, Geekie and Shepherd 1999), thus creating a false belief that they have already reduced their consumption adequately (Rowe and Booth 1999). However, the fact that dietary fat consumption has been one of the foremost public health nutrition issues in recent years (Mela 1995), and that there is widely available information on the association between fat, obesity and chronic disease, and which foods should be consumed in moderation (Birch 1992), suggests that this is unlikely to be the primary cause.

It is commonly recognised that fat determines the characteristic flavour and texture of many foods (Drewnowski 1995) and exerts an important influence upon food palatability (Mela and Sacchetti 1991) which, in turn, influences food choice and consumption (Drewnowski and Greenwood 1983; Drewnowski 1995). Despite this, however, understanding of fat perception and the specific sensory appeal held by fats is still very limited and evidence is still, surprisingly, relatively scarce. Research which has been carried out, tends to be limited to the preference and detection of fat in liquid dairy products (i.e. Drewnowski et al 1989), oil-in-water emulsions (i.e. Mela, Langley and Martin 1994) or semi-solid foods (i.e. Mela and Sacchetti 1991), none of which can adequately represent dietary fat. Equally, it has been suggested that sensory perception and preference for fat may to be influenced by individual characteristics, and therefore be subject to large inter-subject variability (Drewnowski 1993). However no published research to date has examined individual differences in response to non-textural taste properties of fats.

Research suggests that sensory responses to reasonably simple taste stimuli, such as sucrose and salt, are fairly consistent (Mattes and Mela 1986; Shepherd, Farleigh and Wharf 1987; Drewnowski et al 1989). In contrast to this, however, sensory perception of fat is much more complex. This can be partially attributed to the fact that fats are responsible for so many different taste and texture qualities within foods, thus it is not always clear which sensory cues are primarily responsible for the perception of "fattiness" (Drewnowski 1992). A demonstration of this can be found in the unique characteristics fat provides for many foods, including the flakiness for pastry, the lightness to cakes and the creaminess for ice-cream and its use as table spreads, dressings and oils for cooking (Anon 1981). In an attempt to classify the texture of fat-containing foods, Yoshikawa et al (1970) reported that a series of descriptions were commonly given, many of which contradicted each other. Examples included "hard," "soft," "creamy," "crunchy" and "chewy". All of this clearly demonstrates the difficulty in trying to establish the sensory cues through which fat is perceived.

Interest in the sensory perception of fats began mainly in the 1980's with Adam Drewnowski and colleagues, who carried out a series of studies, usually involving sweetened liquid dairy products, to investigate human ability to detect fat content. Drewnowski and Greenwood (1983) examined perception of sweetness and fattiness using combinations of milk and sugar, mixed with varying amounts of heavy cream to create different fat concentrations, by 16 normal weight individuals. The results indicated that intensity estimates for fattiness increased with the level of fat concentration. This finding has since been replicated by succeeding studies, also using dairy solutions (Pangborn and Giovanni 1984; Drewnowski et al 1985; Tuorila 1987; Mela 1988; Drewnowski et al 1987; Drewnowski et al 1989; Drewnowski and Schwartz 1990), suggesting that humans are able to reliably judge changes in fat content in liquid dairy products.

The ability to discriminate between differing fat contents has mainly been attributed to textural cues (Mela 1988; Drewnowski 1993) and specifically to the sensation of creaminess in liquid dairy solutions (Kokini and Cussler 1984). Indeed, a much cited study by Mela (1988), involving milk products of differing fat concentrations, reached the overall conclusion that perception of fat content in dairy fluids is "largely, if not wholly derived from textural sensations within the oral cavity" (Mela 1988, p. 42).

Such claims are further supported by the findings of a study, which deceived participants by creating the illusion of elevated fat content by adding gelatin-based stabilizers and hydrocolloid thickeners to dairy solutions (Drewnowski and Schwartz 1990).

Further support for the importance of texture in detecting fat can be found in research using oil-in-water emulsions. A study by Mela, Langley and Martin (1994) used oil-in-water emulsions of differing fat levels to investigate factors which contribute to the sensation of fattiness. Results indicated that increased viscosity was the major determinant in accurately perceiving fat content in the emulsions. Such findings can be related to a previous study, which involved the assessment of a dry, corn based stimuli coated in differing amounts of oil (Mela and Christenson 1987). These results also indicated that oiliness and viscosity were the primary cues for fat detection (Mela and Christenson 1987).

Whilst the findings of these studies all provide support for the claim that fat perception is driven by textural cues, it is also possible that textural cues are much more apparent in liquid dairy products, oil-in-water emulsions and oil coated stimuli, than in regular solid foods. The fact that such studies tended to formulate taste stimuli by adding graded amounts of milk-fat or oil to a low-fat base also means that noticeable differences in appearance may result, which even attempts at visual masking may not overcome (Tuorila 1987). Equally, the fact that only a small proportion of dietary fat is derived from dairy products (Block et al 1985), and that no single, common textural attribute can be found in fat-containing solid foods means such findings make it very difficult to offer definitive conclusions from the existing research into sensory perception of fat taste.

Very little published research has explored perception of fat taste in a wide range of "real foods," however a few studies have examined a limited selection of liquid and semi-solid foods with varying amounts of fat. A small scale study carried out by Wendin, Ellekjaer and Solheim (1999) examined 11 participants assessment of mayonnaises of differing fat content (700g per kg and 820g per kg) and homogenisation. Results indicated that the sample with higher fat content was perceived as thicker, "fatter," sourer and less sweet than its lower fat counterpart and that variation in fat content appeared to have a greater effect upon perceived sensory attributes than homogenisation. However the value of these results is reduced by the fact that the lower fat mayonnaise sample had a higher sugar content and therefore differences in the sensory properties cannot be reliably attributed to variation in fat content.

Drewnowski et al (1989) examined participant's abilities to evaluate fat content, creaminess and sweetness of sweetened dairy fluids and sweetened blends of cottage cheese and cream cheese containing differing levels of fat. Whilst results for the liquid dairy products replicated earlier findings, that participants could reliably judge fat content (i.e. Drewnowski and Greenwood 1983; Pangborn and Giovanni 1984; Drewnowski et al 1985; Tuorila 1987; Mela 1988; Drewnowski et al 1987; Drewnowski et al 1989; Drewnowski and Schwartz 1990), assessment of fat content in the semi-solid food stimulus was found to be impaired. A further study, using a stimulus similar to cake frosting, composed of varying levels of sucrose, butter (15-

35%), polydextrose and distilled water, found that perceived fat content was poorly related to actual fat content (Drewnowski and Schwartz 1990). Detection of fat was, however, dependent upon the texture of the stimulus, and was thus influenced by polydextrose and water content, as well as actual fat content (Drewnowski and Schwartz 1990).

Several other studies have also attempted to examine fat detection in a battery of semi-solid foods such as mashed potatoes, chicken spread and scrambled eggs (Mela 1990; Mela and Sacchetti 1991; Tepper, Shafer and Shearer 1994), with overall results suggesting that perception of fat is food-specific. It has been argued that this is due to the fact that fat perception primarily results from textural cues (Drewnowski 1992; Mela and Marshall 1991) and no single textural attribute can be found in solid foods (Tepper, Shafer and Shearer 1994). Equally, the texture of fat in solid foods may easily be hidden within the food's matrix (Drewnowski et al 1989).

Whilst the influence of texture upon fat perception has been studied to a certain extent, the possibility that humans may respond to fat as a result of its unique flavour has been neglected until recently. Evidence from a number of studies on rats had suggested that the animals were able to detect and discriminate between flavours of different fats (i.e. Boutwell et al 1944; Larue 1978), but this ability was still believed to be the result of textural cues, rather than a unique fatty flavour (Hamilton 1964; Reed and Friedman 1990). This can be placed into question by evidence indicating that rats are also able to reliably distinguish between and show a consistent preference for nutritive (i.e. corn oil), as opposed to non-nutritive (i.e. Vaseline, mineral oil) fat samples (Smith and Greenberg 1991), despite the fact that such samples could be expected to provide very similar textural cues. When considering human perception of fat, the consensus has been that the presence of fat cannot be associated with any of the basic taste sensations of sweet, salty, sour or bitter, despite the fact that this has not been explicitly tested (Mela 1988).

Recent physiological evidence has, however, refuted this conventional wisdom that fat is intrinsically flavourless and has provided the first direct evidence that, in rats at least, there may be a gustatory cue elicited by fats (Gilbertson et al 1997). Gilbertson et al (1997) performed patch-clamp recordings on isolated rat taste receptor cells in an attempt to determine whether any chemosensory cues were provided by fat in the oral cavity. It was discovered that free fatty acids, generated via the action of lingual lipase in the mouth following fat ingestion, directly effected rat taste receptor cells. The findings indicated that 98% of the receptor cells responded to polyunsaturated fatty acids, though no significant effects were found for saturated or monosaturated fats. This could suggest that the reason there is difficulty in describing the taste of fats is not because they have no taste, but rather because they stimulate all sensory receptors.

The fact that this evidence was solely derived from the study of rats suggests that caution may be required in generalizing the findings to humans. This is particularly necessary as physiological evidence has indicated that the presence of lingual lipase, a vital component within this mechanism in rats, is limited in humans (Spieleman et al 1993). However, Gilbertson et al's (1997) findings also suggested that free fatty acids may enhance the response of taste receptor cells to other taste stimuli as a result of the nature of their effect upon K+ channels. The fact that human psychophysical research has demonstrated an apparent correlation between fat content and the perceived intensity and hedonics of sweetness in sweet-fat mixtures (i.e. Drewnowski and Greenwood 1983; Drewnowski et al 1985; Johnson, McPhee and Birch 1991) provides support for the hypothesis that this general fat-responding mechanism may also be present in some form in humans (Gilbertson et al 1997). In addition to this, Gilbertson has also reported informally that humans are able to describe the taste of fat, but with large individual differences, with some claiming it has a sweet taste, whilst others report sour or salty flavours (No published data. *The Guardian* (London Newspapers), 3rd March 1998, pp16). A study carried out by Schiffman et al (1992) is also consistent with the theory of a possible role for the taste system in human fat perception. Results of this study revealed that sensations from deodorized triglycerides could be detected on the lateral posterior sides of the tongue in the absence of any tongue movement. This suggests that some component of fat may activate taste nerves in humans (Schiffman et al 1992).

A follow-up study by Gilbertson et al (1998) has also since been carried out. Patch clamp-recordings on taste receptor cells were once again applied, but using two strains of rats with different dietary preferences; Osborne-mendel rats who show significant preference for a high fat diet and S5B/P1 rats who ingest little fat, preferring a carbohydrate-rich diet. The results replicated Gilbertson et al's (1997) initial findings derived from Sprague-Dawley rats, but also found that there was a greater effect of polyunsaturated fatty acids upon the taste receptor cells of the fat-avoiding rats compared to the fat-preferring strain. It was thus suggested that this implies an inverse correlation between dietary fat preference and sensitivity to fat (Gilbertson et al 1998).

Despite the implications which these findings may have for human fat perception, the current consensus still maintains that oral perception of fat content is fundamentally guided by textural, rather than flavour, cues (Nestle et al 1998) and no published research has examined the influence of flavour and taste upon human fat perception.

Chapter 2

Individual Differences in the Sensory Perception of Fats

Research has indicated that, despite human's overall preference for fat-containing foods (Drewnowski 1990; Wardle and Solomons 1994), hedonic response to fat, like detection, is also food-specific (Tuorila 1987; Drewnowski et al 1989; Tepper, Shafer and Shearer 1994). Such evidence also indicates that these responses are also subject to considerable individual variation (Drewnowski 1993). No existing, published research has focused upon the non-textural taste characteristics of fats. However the recent findings of Gilbertson et al (1997; 1998) demonstrating the responsiveness of rat taste receptor cells to fat and the variation found between differing rat strains provides evidence to suggest that individual differences may also exist in human perception of the taste qualities of fat. This chapter will consider existing evidence pointing to a number of personal characteristics and factors which may play a role in influencing and determining individual differences in the assessment of the taste qualities of fats.

Dietary Composition

Some existing evidence indicates that hedonic responses to the sensory characteristics of foods may be modified or determined by extended sensory and dietary exposure to them (Mela, Trunck and Aaron 1993). Such an example can be found in the fact that preference for the taste of salt has been found to alter when dietary salt intake has been increased or reduced, leading to enhanced or decreased preferences (i.e. Bertino et al 1982; Blais et al 1986). Whether such a phenomenon exists where dietary fat is concerned is unclear. Whilst dietary exposure to fat has been found to alter fat acceptance in rats, with a high-fat diet leading to increased preference (Rogers 1985; Ramirez 1986; Reed et al 1988; Tepper and Friedman 1989; Lucas and Sclafani 1990; Reed and Friedman 1990), evidence in humans is less conclusive.

Dietary composition in humans may simply reflect food preferences, as opposed to determining them, although evidence regarding personal, social and contextual factors would demonstrate that this is over-simplistic, since factors such as weight concern, lifestyle, budget, advertising and familial and peer influence have all been found to influence food choice and consumption (Pangborn and Giovanni 1984; Reed et al 1997; Nestle et al 1998). Nevertheless, research does demonstrate that dietary composition may be related to individual differences in response to dietary fat.

Some evidence has suggested that the fat content of an individual's overall diet is related to their sensory preferences for fat. A study in which participants created their preferred dairy mixtures using cream and non-fat milk, found that those who reported higher intakes of dietary fat created mixtures which were higher in fat content (Pangborn, Bos and Stern 1985). However, when measures of discrimination, preference and perceived intensity were taken for milk and chocolate milk of varying fat content, results indicated that these factors appeared unrelated to either dietary fat intake or type of milk usually consumed (Pangborn, Bos and Stern 1985).

Other, similar studies have also found conflicting results when examining the relationship between dietary composition and fat detection and preference. Pangborn and Bos (1984) compared dietary intake of dairy products and dairy fat (information derived from food intake questionnaires) with participants hedonic and intensity ratings of dairy fluids with varying fat content (0-16% fat). Their findings demonstrated a variable range of both scores across differing dietary intakes and that, whilst individuals with higher dairy fat intake tended to prefer higher fat levels in the experimental stimuli, this trend was non-significant.

It could be argued that these results may be partly attributed to the fact that only dairy fat intake was measured, which may not give an accurate portrayal of overall dietary fat. However a study by Mela and Sacchetti (1991), in which 10-day dietary records were compared with hedonic response to ten foods, including mashed potatoes, tuna fish and scrambled eggs prepared with differing quantities of fat, reported findings which were equally inconclusive. No correlation was found between dietary fat intake and preferred fat level in the battery foods, nor did any single food or subset of foods show any consistent relationship with individual fat intake.

Despite these negative findings, however, evidence can be found to suggest that dietary fat intake is related to sensory detection and preference. Unpublished observations by Mela (1989, no published data, cited in Mela and Sacchetti 1991), suggested that individuals consuming reduced-fat diets showed decreased preference for fat. Such claims are supported by several follow-up studies of people consuming long-term low-fat diets, which have found a reported decrease in preference for fat and fat-containing foods (i.e. Laitinen et al 1991; Kristal et al 1992). Mattes (1993) carried out a 24-week study examining the effect of a reduced-fat diet on fat preferences and reported that long-term exposure can lead to a reduction in the level of fat preferred in foods. However results suggested that this was only the case when no reduced-fat or fat-substituted discretionary fat sources (e.g. salad dressing) were used.

Whilst the findings of the latter study have been criticised for being ambiguous and failing to give clear evidence for a shift in hedonic preference for fat (Rolls 1993), it still provides some indication that dietary composition is related to fat preference. Evidence from studies in short-term dietary fat manipulation has also been used to suggest that mere exposure may be sufficient to alter fat preferences (Mela and Catt 1995). A study in which participants were given either fat-free or regular-fat potato chips *ad libitum* for an afternoon snack during a 10-day period, found that fat and energy intake were significantly reduced after fat-free potato chips, when compared to regular-fat (Miller et al 1998).

It is, perhaps, surprising that such a significant shift was detected after relatively little manipulation of dietary fat. Particularly since a study by Mela, Trunck and Aaron (1993), in which participants were given reduced and full-fat versions of potato crisps and cheddar cheese to use during a 3-week period, demonstrated no influence upon blind sensory testing or hedonic ratings of these stimuli, leading to the conclusion that dietary manipulation and exposure may have been insufficient (Mela, Trunck and Aaron 1993).

Of those studies which have examined dietary composition and sensory response to fats, participant numbers were usually small (below 30), methodology has been extremely variable and no detailed assessment of dietary composition has been made. This could help to explain the inconclusive nature of the findings so far. In particular, no previous research has examined the relationship between the type of dietary fat most regularly consumed and sensory perception of fat. Gilbertson's informal observations that humans were able to describe the taste of fat, but that some described a sweet taste, whilst others described a sour or salty flavour (no published data. *The Guardian* (London Newspapers), 3rd March 1998, pp16), could be used to suggest that the specific way in which fat is perceived is influenced by or related to the primary source of fat in an individual's diet. The perception of those whose intake comes mainly from sweet high-fat foods may differ from those whose primary source is fried savoury foods.

Body Mass

Existing evidence regarding the relationship between body mass and sensory perception of fats tends to be concerned with differences in preferences and ability to detect fat between normal weight and obese individuals (studies have also examined detection and preferences of individuals with eating disorders, but this will be considered elsewhere). Whilst it is well established that excessive dietary fat consumption is a primary cause of obesity (Danforth 1985; National Academy of Sciences 1989; Lichtenstein et al 1998), evidence has also indicated that body composition may also be linked to the way in which fat is perceived.

The majority of existing studies have examined the relationship between hedonic response to fat and body weight (i.e. Drewnowski et al 1985; Warwick and Schiffman 1990; Mela and Sacchetti 1991), as opposed to the specific way in which fat is perceived. However a study to examine the effects of familial loading for childhood obesity, also investigated psychophysics of fattiness in sweetened dairy fluids of differing fat content (Epstein et al 1989). The findings demonstrated that perception of fattiness was less intense in obese children in comparison to lean individuals (Epstein et al 1989). Obviously further research is needed to build upon these results.

Some past researchers have suggested that obese individuals possess a "sweet tooth" when compared to a normal weight population (Pangborn, Bos and Stern 1985). The fact that this traditionally refers to an enhanced liking for sweet high-fat foods, such as pastries and ice-cream however, led Drewnowski (1985) to suggest that the term "fat tooth" may be more accurate. To test this theory, the relationship between body weight and preference for fat in sweetened dairy fluids containing 0.5-52% fat was examined (Drewnowski et al 1985). Results indicated that, whilst no differences existed in accuracy of perceived fat content, obese individuals preferred higher levels of fat in comparison to normal weight participants. By applying the mathematical algorithm Response Surface Method (RSM), it was found that the average optimally preferred fat level in obese individuals was 34%, compared with 21% for normal weight (Drewnowski et al 1985). However, the fact that research indicates that the major sources of dietary fat in the UK and Western nations actually tend to be savoury, rather than sweet (Gregory et al 1990) suggests that these findings may only partially address potential differences in responses to fat between lean and obese individuals.

However, such findings have also been replicated in a study by Mela and Sacchetti (1991) examining hedonic response to ten foods of wider taste qualities, including mashed potatoes, tuna fish and scrambled eggs prepared with differing quantities of fat. Results demonstrated a positive correlation between overall fat preferences and adiposity (total and percentage body fat and BMI). Whilst such evidence would all seem to point to a clear relationship between body weight, and in particular obesity, and sensory preference for fat, other conflicting findings have prevented a consensus from being reached.

Warwick and Schiffman (1990), using dairy fluids of varying fat content as test stimuli, found no clear evidence for enhanced fat preferences in obese individuals. These results, however, may have been affected by the fact that, in addition to using sweetened dairy solutions, fat-salt mixtures were used which were generally disliked by all participants (Warwick and Schiffman 1990). However such a non-significant relationship between body weight and detection and preference for fat has also been found in studies using milks and chocolate milks (Pangborn, Bos and Stern 1985), oil-in-water emulsions (Mela, Langley and Martin 1994) and cake frostings (Drewnowski, Kurth and Rahaim 1991) of varying fat contents.

The findings discussed so far have all been based upon laboratory studies using stimuli of differing fat contents. However a study by Cox et al (1998) attempted to examine the responses of lean and obese individuals to a selection of "real foods," although a questionnaire method was actually applied as opposed to taste response to actual foods. 23 obese and 20 lean non-dieting individuals assigned pleasantness ratings and perceived predominant sensory attributes to 50 foods in 14 food groups including milk products, cakes and biscuits, fats and oils and meat products. Results indicated no significant differences in hedonic ratings but it was found that lean participants assigned higher preference scores to foods self-classified as sweet and salty/savoury and to those foods grouped in the highest and lowest quintiles of percentage food energy derived from fat. Correspondence Analysis also indicated that obese individuals associated fatty textures with the term "dislike extremely." The fact that these findings were derived from questionnaire responses as opposed to actual taste tests could have increased the possibility of obese individuals giving what they perceived as the desirable responses. However this does not fully explain the fact that these results are also in direct conflict with those suggesting an elevated preference for fat in obese or overweight individuals.

Aside from the effects of methodological differences, one possible explanation for these conflicting results is the argument that obese individuals rarely behave as a homogenous group (Drewnowski 1985), therefore making distinctions on the basis of current body weight alone is too simplistic and may obscure individual differences which are related to body composition. Drewnowski and Holden-Wiltse (1992) examined the relationship between weight history, in particular the presence of weight cycling or "yo-yo dieting," and responses to ice-cream samples of varying sugar and fat content. Results indicated that weight cyclers demonstrated significantly greater preference for ice-cream overall and also rated sweet high-fat desserts as higher on a food preference questionnaire, when compared to non-cyclers. Thus it appears that weight-loss behaviour and fluctuations may also be related to sensory preference for fat. Similar findings have also been reported by Crystal, Frye and Kanarek (1995), who found that individuals experiencing recent weight fluctuations rated stimuli with high-fat content as more pleasant than weight-stable participants.

A further, related study divided obese individuals into categories according to age of onset of obesity and past fluctuations in body weight, and measured their responses to cake frostings of differing fat content (Drewnowski, Kurth and Rahaim 1991). Results demonstrated that those who were characterised by large fluctuations in body weight had elevated preferences for the sugar and fat mixtures, in comparison to the stable weight group. This led to the suggestion that a heightened sensory response to fat may be associated, not specifically with elevated body weight, but with patterns of weight loss and re-gain (Drewnowski et al 1991).

Once again though, these conclusions can be placed into question. A study of nine "massively obese" males found that individual taste responses to sweetened dairy solutions of differing fat concentration remained unchanged following dieting and subsequent weight loss (Drewnowski et al 1987). Whilst it should be taken into account that the number of participants in this study was extremely small and that it focused only upon a clinical population, such findings could still be used to imply that taste responsiveness to fat is an enduring trait which is not directly related to changes in body weight (Drewnowski et al 1987).

In an attempt to establish more consistent results on the relationship between body composition, fat detection and preference, suggestion has been made that differing sensory profiles in fat preference may be distinguished by subtypes of obesity, as opposed to obesity overall (Drewnowski 1992). It has been claimed that it is possible to differentiate between familial or genetic obesity and late-onset obesity, which is not genetically derived (Drewnowski et al 1991).

The most consistent results relating to differing categories of obesity have been found in research using mice and rats (Reed et al 1997). Studies which have compared fat consumption in rodent strains inbred to become obese, compared to controls, have found large strain differences, with the inbred, obese strain consuming greater quantities of dietary fat than the controls (Schemmel et al 1970; Sclafani and Assimon 1985; Larue et al 1994; Smith et al 1997). Findings from research focusing on human obesity have been less consistent. One reason for this may be that it is not possible to establish a precise definition of genetic obesity (Reed et al 1997) in the way that researchers have when studying mice and rats. Equally, numerous other factors which do not influence rodent fat consumption, are likely to play a role in the perception and preferences of humans.

However, some evidence has been found to suggest that individuals with familial obesity are likely to demonstrate higher preferences for dietary fat. A study in which women with one or more obese parents were defined as genetically obese found a higher reported liking for fat in this category (Heitman et al 1995). Studies have also examined the link between child and parental body weight and fat preferences, which could be used as evidence for the influence of genetic body composition. Fisher and Birch (1995) examined differences in preferences for high-fat foods and dietary fat in 3-5 year olds and related it to parental Body Mass Index (BMI). Results indicated that, although all the children were offered identical menus over the same 30 hour period, fat intake ranged from 25%-45% and those with strongest preferences had a higher usual fat intake and heavier parents than those with the lowest preferences.

A degree of support for the influence of genetic body weight upon responses to fat can also be found in the findings of a recent study by Wardle et al (2001) in which the food preferences of 428 children (aged 4-5 years) were assessed using questionnaires, food intake and taste tasks. Results indicated that children from obese or overweight families demonstrated an elevated preference for fatty foods in taste testing, a decreased liking for vegetables and a more "overeating-type" overall eating style. However it should be noted that this pattern of results was not statistically significant. Therefore, there is no conclusive evidence for the influence of genetic body weight upon fat preferences, as it is equally as possible that parents may have shaped their child's preferences through frequent exposure and consumption (Fisher and Birch 1995).

Whilst there is no evidence to suggest that ability to detect fat differs with body mass, findings suggesting obesity or weight history are related to differing preferences for fats are fairly consistent. Therefore, it could be that, underlying the enhanced preference for dietary fat reported by many studies may be variations in the perceived taste quality of fats.

Eating Disorders

It has been suggested that differing patterns of hedonic judgement may underlie the abnormal eating behaviour found in individuals with eating disorders (Sunday and Halmi 1991). Clinical obesity could be included within the term eating disorder, however this has already been dealt with in the previous section discussing body composition. Equally, binge eating syndrome is also regarded as an eating disorder, but for the purpose of this review, the term will refer primarily to anorexia nervosa and bulimia nervosa, since these are the conditions which have been addressed by existing research relating to dietary fat perception.

Whilst no definite consensus has been reached on the eating patterns of either anorexics or bulimics (Sunday and Halmi 1991), a number of common characteristics for each clinical condition have been found. Individuals suffering from anorexia nervosa often limit food intake to fruit and vegetables and tend to avoid meats, dairy products, sweets, desserts and calorie-dense foods (Russell 1967; Beumont et al 1981; Rosen et al 1986; Sunday and Halmi 1991). One redundant belief was that anorectic eating behaviour was defined by "carbohydrate phobia" (Simon et al 1993), but more recent clinical (i.e. Drewnowski et al 1987) and cognitive studies (i.e. Drewnowski et al 1988) have indicated that anorexics primarily reject foods which are rich in fat. Thus it has been claimed that fat avoidance or aversion determines eating patterns in anorexia nervosa (Drewnowski, Pierce and Halmi 1988).

In contrast to this, is the eating behaviour demonstrated by individuals with bulimia nervosa. Bulimics exhibit recurring episodes of bingeing and purging (Sunday and Halmi 1991), and clinical studies have suggested that binges tend to consist mainly of foods which are high in calories and fat. Typical binge foods include chocolate and sweets, dairy products, sweet high-fat desserts, cookies and salted snacks such as crackers and potato crisps (Russell 1967; Russell 1979; Mitchell and Laine 1985; Rosen et al 1986; Drewnowski 1992). In fact it has been argued that the food preferences of bulimics are often similar to those of obese females (Drewnowski, Pierce and Halmi 1988).

It has been suggested that the differing responses exhibited by individuals with eating disorders are a cultural, rather than a clinical phenomenon, and are the result of society's focus upon the fattening qualities of dietary fats (Simon et al 1993). Therefore, whether these patterns can be attributed to differing sensory responses to dietary fat, is still unresolved. The majority of the relatively few studies which have addressed this issue, have examined both anorexia and bulimia as it is possible for overlap to occur, with some individuals demonstrating symptoms from both conditions (i.e. Sunday and Halmi 1991).

A study by Drewnowski et al (1987), examined taste response to sweetened dairy fluids with differing fat concentrations by emaciated anorectic-restrictors and anorectic-bulimics and normal weight bulimics and controls. Whilst results found no differences between the groups in their detection of fat content, significant differences were demonstrated in sensory preferences for fat. Both emaciated anorectics and bulimics disliked intense concentrations of fat when compared to controls and no differences in preference could be found between these two groups. These findings led to the proposal that individual taste preferences may be linked to long-term body weight status, as opposed to clinical condition. However, the fact that no differences in taste response profiles were detected after weight gain in the emaciated participants refuted this (Drewnowski et al 1987). Thus, it was claimed that abnormal taste responses to fat may be an enduring trait within eating disorder patients (Drewnowski et al 1987).

Drewnowski et al's (1987) finding that detection of fat content did not differ between individuals with eating disorders and controls has been replicated by other studies, using both liquid dairy products (Sunday and Halmi 1991) and soft dessert cheese (Simon et al 1993). However, consistent differences in hedonic responses to fat have been observed, also supporting the findings of Drewnowski et al (1987). In a similar study, also using sweetened dairy solutions, Sunday and Halmi (1991) found that both anorectics and anorectic-bulimics showed an aversion to high-fat stimuli compared with controls. These findings however, suggested that, whilst the taste hedonics of the anorectic-bulimics appeared to be a stable trait, those of anorectics actually changed with weight restoration (Sunday and Halmi 1991). Further replication for anorexic's dislike of sensory stimuli rich in fat, was also found in a study using soft dessert cheese thickened with heavy cream for varying fat contents (Simon et al 1993).

The fact that no impairment in ability to detect fat has been found would suggest that eating disorders are not characterised by any deficiency in taste. However the consistent differences in hedonic responses to fats in individuals with eating disorders which have been reported, could be used to suggest that they may also perceive fats as having different taste qualities compared to a normal population.

PROP Sensitivity

6-*n*-Propylthiouracil (PROP), along with phenythiocarbamide (PTC) are members of a class of compounds defined as thioureas, which are characterised by a bitter taste or flavour (Tepper 1998). The ability to perceive the bitterness of these compounds is genetically determined (Bartoshuk et al 1994), with around 30% of adult caucasians being taste-blind to PTC/PROP (labelled non-tasters), whilst the remaining 70% are tasters (Blakeslee 1931; Snyder 1931). Thus tasters are defined by their low thresholds of sensitivity to PROP/PTC, and can be further classified as medium-tasters and supertasters (Bartoshuk et al 1994), whilst non-tasters exhibit extremely poor sensitivity even at very high concentrations (Tepper 1998). Most recent studies have replaced PTC with PROP, due to the fact that PTC has a slight odour (Tepper 1998).

It has been found that the number and distribution of fungiform taste papillae on the anterior surface of the tongue is functionally related to taste perception (Arvidson and Friberg 1980; Miller and Reedy 1990; Tepper and Nurse 1997). PROP tasters have been found to have higher taste bud densities and more taste cells than non-tasters (Miller and Reedy 1990), with supertasters having the greatest number of fungiform papillae and highest density of taste pores (Bartoshuk et al 1994). This appears to be responsible for the differences in taste which have been observed between PROP tasters and non-tasters.

Studies have found that PROP tasters show greater sensitivity to a wide range of different oral stimuli, including caffeine (Hall and Bartoshuk 1975) and capsaicin (Bartoshuk et al 1994; Tepper and Nurse 1997). Tasters have also been shown to prefer mild, as opposed to sharp tasting foods (Forrai and Bankovi 1984) and have more overall food dislikes (Fischer, Griffin and England 1961; Kaplan and Glanville 1965). Recent evidence has suggested that genetically determined PROP taster status also extends its influence to differences in fat perception.

A study by Duffy et al (1996) examined the relationship between oral fat detection and PROP taster status using milk products of varying fat content (0.5-54%) which were rated for creaminess. Results demonstrated that supertasters gave the highest creaminess ratings for high-fat stimuli. Such enhanced sensitivity to fat has also been reported in a study in which ratings were given for salad dressings with differing fat contents (Tepper and Nurse 1997). Medium and super tasters were found to be able to discriminate between dressings containing 10% and 40% fat, whilst non-tasters could not (Tepper and Nurse 1997).

In contrast to these findings, however, a study by Drewnowski, Henderson and Barratt-Fornell (1998) using sweetened dairy fluids of differing fat concentration found no link between PROP taster status and oral detection of fat. A number of explanations have been proposed for this, including the possibility that the population selected was too narrow, since all participants were young normal weight females, who were not dieting or smoking (Drewnowski Henderson and Barratt-Fornell 1998). Equally it could be that fat content may have been masked by the sweetness of the sucrose in the stimuli (Tepper 1998). However these findings were supported by a recent study in which 40 non-tasters, 67 medium tasters and 40 super-tasters rated food samples such as potato chips, mashed potatoes and vanilla pudding of varying fat contents for perceived intensity of fattiness, saltiness and sweetness (Yackinous and Guinard 2001). Overall, taster status was unrelated to the perceived taste qualities of the stimuli.

PROP sensitivity has also been linked to differing preferences for dietary fat and fat containing foods. Tasters have been found to have a lower reported preference for whipped cream than non-tasters (Forrai and Bankovi 1984). More extensive differences have been reported in a study by Duffy, Weingarten and Bartoshuk (1995), which looked at the association between PROP taster status and reported preference for 82 foods and beverages and found that, overall, tasters claimed to have lower preferences for high-fat foods. Evidence has also suggested that female supertasters have lower Body Mass Indices than medium or non-tasters (Lucchina et al 1995) and that supertasters are less likely to consume or prefer high-fat foods (Dabrila et al 1995; Duffy et al 1995; Lucchina et al 1995). Sensory evidence has also supported this, with the finding that non-tasters showed significantly greater preference for high-fat salad dressing (40% fat), as opposed to a lower fat dressing (10% fat), when compared to medium and supertasters (Tepper and Nurse 1997).

Evidence has also suggested that gender differences may effect the specific way in which PROP tasters and non-tasters respond to dietary fat. In a study of 22 men and 24 women, Duffy and Bartoshuk (2000) found that the association between genetic taste measures and acceptance of sweet and high-fat food and beverages differed between males and females. Whilst women's preference for sweet and high-fat food and drinks decreased with increasing perceived bitterness of PROP, in men liking for these foods and beverages actually increased with increasing papillae densities.

In contrast to the findings suggesting that PROP sensitivity tends to be associated with a decreased preference for dietary fat, are the results from a study by Tuorila et al (1997), examining the influence of fat and salt content upon perception of cream cheese samples by PROP tasters and non-tasters. It was found that the "high-taster" (or supertaster) group reported the greatest preference for high-fat stimuli, whilst the non-taster group gave lowest preference ratings. One possible explanation for these unexpected findings is that the presence of salt in the sample influenced fat perception. However, the fact that results regarding the perception of salt were also contrasting to previous evidence concerning PROP sensitivity (Tuorila et al 1997) would suggest that methodological factors may also be responsible.

Overall, the current consensus suggests that PROP taster status may influence individual differences in both sensory detection and preference for dietary fats. One explanation for this is the fact that anatomical studies of rodents have found that taste buds are surrounded by trigeminal fibres (Whitehead and Beeman 1985), thought to be associated with textural perception (Cardello 1996). If this is the case for humans then tasters, with their greater taste bud densities (Miller and Reedy 1990; Bartoshuk et al 1994), would have more trigeminal fibres on the tongue, providing them with an advantage over non-tasters in perceiving fat in viscous fluids, such as salad dressings, and creamy foods, such as dairy products (Tepper and Nurse 1997).

This evidence implies that individual differences in the perception of fats as a function of PROP sensitivity may be due to textural cues from fat. However, previously cited recent research by Gilbertson et al (1998), which found that polyunsaturated fatty acids had a greater effect upon the taste receptor cells of a fat-avoiding strain of rats, compared with a fat-preferring strain, could be used to question this. The fact that both the fat-avoiding strain of rats and PROP tasters have been shown to have greater sensitivity to fat and decreased preference could be used to suggest that individual differences would be found in the perceived taste qualities and flavour of fats by PROP tasters and non-tasters. Such a relationship is, however, highly speculative as no published research has yet addressed this.

Gender

Study of the influence of gender upon individual differences in taste perception of dietary fats is complicated by the fact that that females generally have more negative attitudes towards fat and fat-containing foods than males (Shepherd and Stockley 1987). Thus it can be difficult to establish whether any apparent differences can be attributed to variation in sensory response or, instead to attitudinal factors.

Studies have indicated that, whilst the chief sources of dietary fat for females are sweet high-fat desserts, mayonnaise and dairy products (Drewnowski 1995; Nestle et al 1998), dietary fat in males is derived mainly from red meat such as beef, and fried foods such as chips (Meiselman and Waterman 1978; Meiselman and Wyant 1984; Drewnowski 1995). Differences have also been found in the self-reported food preferences of obese men and women. Whilst obese males tended to prefer steaks, roasts, burgers, fish, eggs, french fries and pizza, obese women listed mainly sugar-fat combinations amongst their preferred foods, selecting ice cream, chocolate, cakes, cookies, doughnuts, pies and desserts (Drewnowski et al 1992; Drewnowski 1992; Nestle et al 1998). However whilst this demonstrates differences in dietary consumption, it cannot be assumed that it reflects sensory preference for dietary fats.

There is little evidence for gender-related differences in the detection of fats in a normal population. Studies examining ability to perceive different levels of fat in liquid dairy products (Drewnowski et al 1987; Warwick and Schiffman 1990) and oil-based salad dressings (Tepper and Nurse 1997) have failed to find any differences in the abilities of males and females. Equally, a number of studies examining hedonic rating for differing levels of fat have found no gender distinctions in fat preference (Pangborn and Giovanni 1984; Drewnowski et al 1989; Mela and Sacchetti 1991). However the sensory stimuli used in these studies were very basic, with only Mela and Sacchetti (1991) making any attempt to use “real foods” which, even then were a limited selection of ten, mainly semi-solid foods.

However, findings from a study by Monneuse, Bellisle and Louis-Sylvestre (1991) indicated that gender effects may be modulated by age. Four age groups of males and females (10-13 years, 14-15 years, 16-19 years and adults whose age was unspecified) were compared for taste preference and acuity for samples of sweetened soft dessert cheese, mixed with heavy cream for differing fat contents. The results indicated that females were able to accurately perceive the fat content of the stimulus at an earlier age than males. The most obvious gender differences were found in the younger age groups, with young girls and adolescent females showing a decreased preference for high-fat stimuli, compared with males. This finding was not replicated in adults.

It has been suggested that the gender related differences in preference found in this study could be related to weight and dietary concerns, as opposed to sensory differences (Monneuse, Bellisle and Louis-Sylvestre 1991). If this were the case however, it would be expected that such effects would also influence the adult females. Equally, it should be taken into account that, the fact that the age range of the adult population was unspecified means that it is not possible to judge the validity of the comparisons between the age groups.

Therefore, whilst evidence suggests that differences exist in the types of foods males and females select as their preferred sources of dietary fat, there is no evidence for any difference between the abilities of men and women to detect the presence of fat and no distinctions in sensory preferences have been found either. This could suggest that variations in food choice are due instead to differences in the perceived taste qualities of fat between males and females.

Support for potential gender differences in dietary fat perception could also be established if the perceived taste qualities of fat are found to be influenced by PROP sensitivity. This is due to the fact that evidence indicates females are more likely than males to be PROP supertasters and thus more likely exhibit more sensitive sensory responses to fat (Bartoshuk, Duffy and Miller 1994).

Age

The general preference exhibited by humans for fat-containing foods is not thought to be innate (Drewnowski 1997), instead researchers have suggested that it is acquired during infancy (Birch 1992; Kern et al 1993). It has been suggested that the issue may be complicated by attitudinal factors in that, whilst children tend to select foods on the basis of their taste alone (Anliker et al 1991; Birch 1992; Birch, Johnson and Fisher 1995), adults are more likely to be influenced by nutrition, weight and dieting beliefs (Logue 1986; Drewnwski 1997). Nevertheless, evidence has suggested sensory differences may also exist as a result of age.

A very recent study has examined reported preferences of elderly people (60-70 years old) and younger adults (18-28 years old) for meats, fish and eggs (Jolivet and Touraille 1999), all of which are fat-containing foods to differing extents, and detected age-related differences. Result indicated that, whilst elderly individuals preferred strong tasting meats such as lamb, the strong flavour was less appreciated by the younger adults who preferred milder flavoured meats such as veal (Jolivet and

Touraille 1999). These findings may no necessarily be indicative of age-related taste variation however, and may simply be reflective of generational differences in food preferences and intake.

This differences in taste preference between the age groups, as a result of flavour strength, could be attributed to declining taste sensitivity with age, thus causing foods with a milder flavour to be perceived as bland and increasing the selection of stronger tasting foods. Studies have found that elderly people often suffer from taste deficits (Bartoshuk 1989; Weiffenback and Bartoshuk 1992), however the extent to which these may impact upon sensory responses and preferences is still unclear. Whilst it has been suggested that such conditions may be responsible for elevating taste thresholds, it has also been argued that many taste deficits are localised leaving whole-mouth tasting ability essentially normal (Bartoshuk 1989).

The influence of ageing upon any form of sensory perception of fats is still unresolved, due partly to a lack of research. However some evidence for age-related differences has been reported. Warwick and Schiffman (1990) collected evaluations of liquid dairy products of differing fat concentrations, mixed with sucrose or salt and found that, in contrast to the younger individuals, elderly participants gave similar hedonic ratings, regardless of fat content. This could suggest a reduced ability to detect fat in the stimuli (Warwick and Schiffman 1990). This has been supported by findings indicating that elderly individuals had increased discrimination thresholds for emulsified fats (Schiffman et al 1992). Possible age effects were also detected by post-hoc analysis for age in a study by Mela, Langley and Martin (1994), which revealed that individuals over the age of 30 rated oil-in-water emulsions as smoother and higher in fat at all levels of fat concentration, particularly the highest. These findings are, however, difficult to interpret and attempts to replicate them have failed (Mela, Langley and Martin 1994).

If, as evidence has suggested, age does lead to impaired ability to detect fat it is also possible that deficits in taste may cause differences in the perceived taste qualities of fats.

Chapter 3

Can the basic tastes of sweet, salty, sour and bitter be detected in fats and oils?

Study 1

Introduction

Fat imparts a wide range of characteristics to foods, ranging from a desirable appearance to the overall flavour, aroma, texture and mouth-feel (Lucca and Tepper 1994). Yet a complete understanding of the functions of fat in foods and the precise sensory qualities of dietary fat itself is still surprisingly lacking. Research has assumed that freshly processed oils and fats typically have no intrinsic flavour (Mela 1990). This would suggest that fat cannot be associated with any specific taste quality. However this has not been explicitly tested by any previous published research and new but accumulating evidence has begun to suggest that there may be a taste component to fat perception. The physiological findings of Gilbertson et al (1997; 1998), indicating that 98% of rat taste receptor cells responded to polyunsaturated fatty acids cast doubt upon conventional wisdom. These results could be used to hypothesise that the reason humans have difficulty describing the taste of fats is not because they are tasteless but actually due to the fact that they stimulate all the major taste receptors. Equally intriguing are Gilbertson's informal reports that humans are able to describe the taste of fat but with large individual differences (no published data. *The Guardian* (London Newspapers), 3rd March 1998, pp16). The possibility of a taste component in human responses to fat is also supported by clinical observations. It has been reported that oral stimulation with dietary fat alters postprandial plasma triaclyglycerol concentration, whereas oral stimulation with a non-fat food matched to its full-fat counterpart for textural properties was not as effective (Mattes 1996). Previously cited research by Gilbertson et al (1998) has also revealed an inverse correlation between the effects of fatty acids on rat taste receptor cells and overall fat preference in rats. Whether this effect can be generalised to humans is as yet unknown.

The aim of this study was to explicitly investigate whether individuals were able to describe a taste component to their sensory responses to fats and oils and, if this were the case, whether any specific taste qualities could be associated with dietary fat. Due to the fact that no previous research had addressed this issue an appropriate starting point was deemed to be whether fats and oils could be associated with any of the four primary taste qualities of sweet, salty, sour and bitter.

The initial identification of these taste primaries has frequently been attributed to Henning (1916) who hypothesised that the description of any given taste could be represented using a taste tetrahedron, with each of the 4 corners of the tetrahedron representing a basic taste (Logue 1991). Throughout the development of sensory research there has been longstanding disagreement between those who regard sweet, salty, sour and bitter as distinct and separate tastes and those who suggest that they simply represent degrees of difference along a continuum (Bartoshuk 1980). Equally, it has been argued that the definition of four primary tastes has no absolute scientific basis and that some chemicals and substances which stimulate taste receptors actually elicit unique tastes which cannot be classified in this way (Kurihara and Kashiwayanagi (1998). Nevertheless the concept of the four primary tastes has been widely regarded as a useful and appropriate means of enabling basic and relatively reliable taste descriptions given the fact that the nature of each taste tends to be universally and consistently recognised. Sensory evidence has also indicated that fifth primary taste – Umami – can be added (Kurihara and Kashiwayanagi 1998). This unique taste is induced by glutamic acid, inosinic acid and guanylic acid. Umami substances can be found in many common foods such as mushrooms, prawns and specific meats and cheeses. However the taste quality is still not widely recognised amongst western societies and therefore was not included within this study.

The study of sensory responses to fat is complicated by the fact that sources of fat are diverse and that fat is very rarely consumed in its pure, or even simple form and is usually only acceptable when presented as a component of a complex food system (Mela 1990) However any taste elicited by the fat is then likely to be altered or even masked by other components within the food. Therefore, for the purpose of this study three variations of pure processed oil were used. In addition, butter was also used as a control stimulus in order to compare taste responses to pure processed oils with a basic fat sample which also contained added ingredients such as salt. In terms of the pure processed oils, both milder (corn oil and sunflower oil) and stronger (walnut oil) tasting samples were selected in order to examine whether derivative ingredient appeared to be a significant component of the taste responses given to the fats.

Edible oils are mainly composed of triacyglycerols with phospho- and glycolipids comprising a small fraction (Shahidi and Wanasundara 1997). Other minor constituents include sterols, waxes, lipid soluble vitamins and phenolics (Shahidi and Wanasundara 1997). Care concerning the nature of storage of edible oils is of particular relevance as exposure to oxygen-containing atmospheres, direct sunlight and heat can all act as catalysts for change and degradation in the taste of the oil leading to “off” or rancid flavours (Mela and Sacchetti 1991; Tian and Dangupta 1999; Williams and Applewhite 1976). Such flavours would in turn alter taste perception of the oil.

On the basis of the above , the following hypotheses have been proposed:

Experimental Hypothesis 1: Individuals will be able to describe the taste of basic fats and oils using the primary taste labels; sweet salty, sour or bitter.

Experimental Hypothesis 2: Preference for the taste of basic fats and oils will be inversely related to perceived intensity.

Method

Design

This study employed a within subjects repeated measures design. The independent variable was the type of fat tasted. Dependent variables were perceived taste qualities and preferences for each sample of fat.

Participants

83 participants were recruited: 64 females and 19 males. Participant ages ranged from 16 - 70 years old and the mean age was 28 years, with a standard deviation of 13.46. 72% (n = 60) of participants were aged 16 – 35, 17% (n = 14) were aged 36 – 50 and 11% (n = 9) were aged 51 – 70 years. 92% (n = 76) of participants were self-reported non-smokers whilst 8% (n = 7) described themselves as smokers. All participants were naïve as to the purpose of the study.

Materials

Stimuli

Sensory stimuli for this study consisted of samples of salted butter ("Moonraker" St Ivel LTD, Swindon, UK), sunflower oil (J. Sainsbury plc, London, UK), corn oil (J. Sainsbury plc, London, UK) and walnut oil (J. Sainsbury plc, London, UK). The fats were stored in a cool, dark environment, in order to minimse interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

Questionnaires

In order to rate the perceived taste qualities and preferences for each sample of fat, participants completed response sheets (see appendix 1), containing 100mm line scales on which they indicated their rating of the stimuli's sweetness, saltiness, sourness, bitterness and liking for taste and texture (all anchored "not at all" and "extremely") and perceived flavour strength (anchored "barely detectable" and "strongest imaginable").

Procedure

A pilot study was carried out prior to this research, in which 10 participants were asked to taste and rate sensory qualities of 7 different fat samples in order to aid the selection of fat stimuli for this study. Non-animal fats were chosen in order to maximise the range of participants able to take part.

Upon recruitment for this study, participants were requested not to smoke, clean their teeth, eat or drink anything except water for 2 hours prior to the study to minimise the risk that their taste perception of the fats would be contaminated. The 4 samples of fat; butter, sunflower oil, corn oil and walnut oil, were presented in small opaque plastic cups, each containing 10ml of the fat stimuli. Plastic spoons were provided for the tasting of the butter. The fats were evaluated separately and presented in a random order and participants were unaware as to the identity of each sample. A standard "sip-and-spit" procedure was employed, in which, after tasting, participants were required to expectorate and complete the relevant sensory rating scales. They were then required to rinse three times with distilled water, spitting out each time, before repeating this procedure with the next sample. Participants were required to take a 5-

minute break between tasting and evaluating each fat sample. This was a recommended time needed to prevent the flavours of the sample being tasted being suppressed by those of the previous sample (Nguyen and Pokorny 1998).

Analysis

Repeated measures analyses of variance (ANOVA) were carried out between perceived ratings of sweetness, saltiness, sourness and bitterness for each individual fat to establish whether particular taste qualities could be established as being dominant in any of the fats. Repeated measures ANOVA were also used to examine whether any differences could be found between fat stimuli in terms of their perceived flavour strength and preferences for taste and texture. Repeated measures ANOVA were carried out between each different fat stimulus to explore whether differences existed for each taste response. Correlations were used to investigate how flavour and texture perceptions related to preferences for the fats.

Results

Mean ratings given by participants for the presence of taste qualities and for perceived intensity and preferences for each fat can be seen in *Table 1.*

Table 1: Mean ratings for the presence of primary taste qualities, taste and texture preference and perceived intensity of fat samples

		Sweet	Salty	Sour	Bitter	Strength	Taste preference	Texture preference
Corn Oil	Mean	19.05	16.29	16.45	17.27	29.70	16.88	22.57
	±	23.27	18.77	22.23	21.84	24.48	17.37	21.12
Walnut	Mean	20.66	28.10	25.70	26.28	53.28	19.20	21.89
Oil	±	21.01	25.93	28.66	27.53	21.88	21.02	20.82
Sunflower	Mean	18.46	16.70	20.95	21.40	28.48	16.94	19.87
Oil	±	21.04	20.57	23.73	25.52	24.20	17.40	18.76
Butter	Mean	33.77	55.16	16.96	13.87	61.08	44.47	43.53
	±	28.90	22.72	20.04	17.98	20.83	25.48	25.11

Repeated measures Analysis of variance (ANOVA) exploring differences between the taste qualities perceived in each fat indicated no significant differences between ratings of sweetness, saltiness, sourness or bitterness for corn oil, sunflower oil or walnut oil. A significant difference between the 4 taste qualities was found in ratings given for butter, $F(3, 246) = 76.859$, $p<0.001$. However Mauchly's Test of Sphericity revealed that this assumption has been violated therefore the adjusted Greenhouse-Geisser corrected estimate was adopted instead, $F(2.133, 174.9) = 76.859$, $p<0.001$. Bonferroni's pairwise post-hoc analysis revealed that the significant main effect reflects differences between ratings of all the taste qualities with the exception of sourness and bitterness, where no significant difference between the presence of these qualities existed.

Repeated measures ANOVA was also used to explore whether particular taste qualities or responses differed significantly between the 4 fat samples:

Sweetness

A significant difference was found between ratings of perceived sweetness given for each fat stimuli, $F(3, 246) = 13.97$, $p<0.001$. However Mauchly's Test of Sphericity revealed that this assumption had been violated, therefore the adjusted Greenhouse-Geisser corrected estimate was adopted instead, $F(2.712, 222.423) = 13.97$, $p<0.001$. Bonferroni's pairwise post-hoc analysis indicated that the significant main effect can be attributed to significant differences between butter and the 3 oil samples. Means in *Table 1* illustrate that butter was perceived as tasting significantly sweeter than the corn, walnut or sunflower oils.

Saltiness

A significant difference was found between ratings of perceived saltiness given for each fat stimuli, $F(3, 246) = 89.024$, $p<0.001$. Mauchly's Test of Sphericity revealed that this assumption was violated, therefore the adjusted Greenhouse-Geisser corrected estimate was applied instead, $F(2.367, 194.107) = 89.024$, $p<0.001$.

Bonferroni's pairwise post-hoc analysis indicated that the significant main effect can be attributed to significant differences between all of the fat samples with the exception of corn oil and sunflower oil which were not perceived as tasting significantly different in terms of saltiness. Means in *Table 1* demonstrate that butter was perceived as tasting most salty, followed by walnut oil, whilst the perceptually similar corn and sunflower oils were detected as the least salty.

Sourness

A significant difference was found between ratings of perceived sourness given for each fat stimuli, $F(3, 246) = 4.962$, $p<0.005$. Mauchly's Test of Sphericity revealed that this assumption was violated, therefore the adjusted Greenhouse-Geisser corrected estimate was applied instead, $F(2.648, 217.142) = 4.962$, $p<0.005$. Bonferroni's pairwise post-hoc analysis indicated that the significant main effect appears due to walnut oil being rated as tasting significantly sourer than butter and corn oil.

Bitterness

A significant difference was found between ratings of perceived bitterness given for each fat stimuli, $F(3, 246) = 7.948$, $p<0.001$. Mauchly's Test of Sphericity indicated that a violation of this assumption had occurred, therefore the adjusted Greenhouse-Geisser corrected estimate was accepted, $F(2.62, 214.815) = 7.948$, $p<0.001$. Bonferroni's pairwise post-hoc analysis indicated that the significant main effect can be attributed to walnut oil being rated as tasting significantly more bitter than butter and corn oil.

Intensity

Significant differences were found between the perceived intensity of taste and flavour of each fat sample, $F(3, 246) = 71.111$, $p<0.001$. As Mauchly's Test of Sphericity indicated that a violation of this assumption had occurred, the adjusted Greenhouse-Geisser corrected estimate was applied, $F(2.741, 224.762) = 71.111$, $p<0.001$. Bonferroni's pairwise post-hoc analysis revealed no significant differences between the perceived strength of walnut oil and butter or between corn oil and sunflower oil. However post-hoc comparisons reveal that both butter and walnut oil were rated as tasting significantly stronger than both corn oil and sunflower oil.

Taste preference

A significant difference was found between the perceived taste preferences for each fat stimuli, $F(3, 246) = 56.275$, $p<0.001$. Mauchly's Test of Sphericity revealed that this assumption had been violated, therefore the adjusted Greenhouse-Geisser corrected estimate was applied, $F(2.443, 200.289) = 56.275$, $p<0.001$. Bonferroni's pairwise post-hoc analysis revealed significant differences between butter and each of the 3 oil samples. Means, presented in *Table 1*, indicate that butter was given significantly greater hedonic taste ratings than the corn, walnut or sunflower oils.

Texture Preference

A significant difference was found between hedonic ratings for the texture of each fat, $F(3,246) = 36.94$, $p<0.001$. Mauchly's Test of Sphericity revealed that this assumption was violated, therefore the adjusted Greenhouse-Geisser corrected estimate was adopted, $F(1.91, 156.657) = 36.94$, $p<0.001$. Bonferroni's pairwise post-hoc analysis indicated that the significant main effect can be attributed to differences between butter and each of the 3 oil samples. Means, presented in *Table 1*, illustrate that butter was given greater hedonic ratings for texture than corn, walnut or sunflower oil.

Correlations were carried out to examine the relationships between perceived strength and texture preferences and overall hedonic responses to the taste of each fat:

Intensity

A significant positive correlation was found between the perceived strength of the taste of butter and overall taste preference, $r = 0.288$, $p<0.01$. $R^2 = 0.23$, indicating that 23% of variability in overall taste preference for butter can be accounted for by its perceived strength. No significant correlations were found between perceived strength and taste preference for any of the oils.

Texture Preference

Significant positive correlations were found between texture preferences and hedonic response to the taste of each fat sample:

Corn oil: $r = 0.483$, $p<0.001$. $R^2 = 0.23$, indicating that 23% of variability in hedonic response to the taste of corn oil can be accounted for by preference for its texture.

Sunflower oil: $r = 0.628$, $p<0.001$. $R^2 = 0.39$, suggesting that 39% of variability in preference for the taste of sunflower oil can be accounted for by liking for its texture.

Walnut oil: r = 0.556, $p<0.001$. $R^2 = 0.31$, which indicates that 31% of variability in hedonic response to the taste of walnut oil can be accounted for by preference for its texture.

Butter: r = 0.716, $p<0.001$. $R^2 = 0.51$, suggesting that 51% of variability in liking for the taste of butter can be accounted for by hedonic response to its texture.

Discussion

The findings of this study indicated that, when aggregating the data across all individuals, it appeared that participants were able to detect the primary taste qualities of sweet, salty, sour and bitter in the fat samples tasted. To a certain extent this in itself supports hypothesis 1, which stated that *"Individuals will be able to describe the taste of basic fats and oils using the primary taste labels; sweet salty, sour or bitter."* Repeated measures ANOVA also revealed that for butter, the primary taste qualities of sweet and salty were significantly more intense and thus appeared to be specifically associated with butter's overall taste. However, no specific taste quality could be specifically related to corn, walnut or sunflower oil. These differences between responses to the fats may be related to the fact that commercially produced butter contains more additional additives than oils, including salt as a major component. Therefore the taste qualities perceived in the butter cannot be completely attributed to the fat component of the stimulus.

Whilst the above findings to appear to give support to Mela's (1990) assertion that fat cannot be specifically associated with any particular or specific taste quality, they also still appear to provide encouraging endorsement to the findings of more recent research indicating that there is a gustatory component to sensory responses to fat (Gilbertson 1997). The results also support Gilbertson's informal findings that humans are able to describe the taste of fats. In reporting this, Gilbertson also stated that marked individual differences existed. This may well be the case for this study, but since data has been aggregated across all individuals, this would have masked any individual differences by assuming that all participants behave the same. Such methods of analysis may also be partially responsible for the similarity between ratings of each taste quality given for the oils. If individual differences did exist in the taste qualities perceived to be most intense these may have been averaged into more consistent rating scores by aggregating the data into means for analysis.

Pearson's correlation analysis revealed a positive correlation between the perceived intensity of the taste of butter and overall taste preference. Repeated measures ANOVA also indicated that butter was perceived as tasting significantly more intense than either corn or sunflower oil and was given significantly greater hedonic ratings than any of the oils. This finding was actually the opposite to that proposed in Hypothesis 2, which stated; *"Preference for the taste of basic fats and oils will be inversely related to perceived intensity."* No significant correlation could be found between perceived intensity and overall taste preference for any of the oils. However, repeated measure ANOVA revealed that walnut oil was perceived as tasting significantly saltier, than corn oil and sunflower oil and significantly sourer and more bitter than butter and corn oil and was rated as significantly more intense than sunflower or corn oil. Walnut oil was also ascribed higher hedonic ratings than either corn or sunflower oil (though this was a non-significant finding), upholding the trend of this data, which could suggest that the more intensely taste of fat is perceived the greater the hedonic rating. As previously cited, Gilbertson et al (1998) reported an inverse correlation between the effect of fatty acids upon rat taste receptor cells and overall preference for fat in rats. The results of this study provide no evidence of such an effect in humans.

One explanation for these findings is the possibility that scores of intensity, either overall or for given taste qualities, had not reached an appropriate level to become aversive. Equally, as previously discussed, findings based upon aggregated data may have led to more extreme responses being averaged out. It should also be taken into account that, where a positive correlation was found for butter, between intensity and preference, only 23% of variability in hedonic ratings could be accounted for by intensity.

Repeated measures ANOVA revealed that butter was given significantly higher hedonic ratings for both taste and texture than the 3 oil samples. As has been discussed previously butter cannot be directly compared to pure processed oils, due to its greater number of taste-related additives. However this finding could also be attributed to familiarity, given that butter is consumed regularly by many, in an undisguised form (i.e. on bread, vegetables, etc). By comparison pure oils are very rarely consumed in detectable form and are more likely to be used as a cooking base. The fact that different fats appeared to generate varyingly different taste responses indicates the validity of using more than one fat stimuli.

Pearson's correlation analysis indicated positive correlations between preference for texture and overall taste hedonics for each of the fat stimuli. As has been previously discussed, much evidence has attributed responses to fat as being based upon textural cues alone (i.e. Mela 1988; Drewnowski 1993) and these results could indicate that individual's taste preference is being influenced by textural cues, as taste cues are not strong enough. However this seems fairly unlikely as the strongest correlation between taste and texture is found for butter (51% variability is taste preference explained by texture preference), which was also perceived to be the most intense tasting. More likely, is the possibility that taste and texture cues are simply difficult to separate when individuals are determining their preference.

The use of commercially-available fats as stimuli for this study was deemed appropriate due to the fact that they are the types of fats people consume as part of their daily diet. As previously discussed, care was taken to store the fats appropriately prior to use, to prevent changes or degradation in flavour due to interaction with factors such as direct light, heat, etc. This could have altered the perceived taste of the fats and thus affected results of this study. It must be taken into account that the fats had been stored in unknown conditions prior to purchase but these would be expected to be appropriate, as companies will wish to ensure good quality products to protect their own reputations. Equally previous research indicates that rancidity in fats was hardly perceived by trained assessors unless oxidation had occurred to a high degree, such as after frying (Nguyen and Pokorny 1998). Therefore this suggests that any slight inadvertent changes would be unlikely to have effected the results of this study.

In conclusion, the findings of this study provide some preliminary indication that individuals may be able to describe taste qualities of fats and therefore that there may be a gustatory component to taste responses to fat. However this study also further reinforces the fact that, if this is the case, tastes elicited by fats are both complex and subtle and are unlikely to be adequately explained by requesting forced-choices response ratings of the four primary taste qualities. Therefore, further analysis is required allowing individuals to generate their own taste responses. Equally the possibility of individual differences, which may play a major role in determining responses to fat, needs to be addressed and explicitly tested.

Chapter 4

Individual differences - The relationship between age, gender and taste responses to fats

Study 2

Introduction

The findings of the previous study provided some initial indication that individuals may be able to describe taste qualities of fats and therefore that there may be a gustatory component to taste responses to fat. This evidence gave some preliminary suggestion that Gilbertson's (1997; 1998) findings relating to the ability of rat taste receptor cells to respond to fat may be of relevance to humans. However, Gilbertson's informal reports had also suggested that humans could describe the taste of fats, but with marked individuals differences. This was not clarified in the previous study due to the use of aggregated statistical analysis methods.

Therefore, the aim of this study was to investigate whether individual variation exists in people's detection of taste qualities and hedonic responses to fats through the use of multidimensional scaling. Some preliminary attempt was also made to investigate factors that may potentially lead to and influence individual differences by focusing upon the relationship between individual's taste responses to fat and demographic characteristics gender and age.

Multidimensional Scaling

Sensory data is typically aggregated across all respondents with the implicit assumption that all participants exhibit the same behaviour and thus that a single mean value or summary statistic is representative of the whole given population (Greenhoff and McFie 1994). However this fails to account for individual variations and, as has been previously discussed, previous research addressing sensory responses to fat has yet to investigate whether there are individual differences in the way people ascribe taste qualities and preferences. Therefore an attempt to address this deficit was made by using the multidimensional scaling technique of internal preference mapping or MDPREF. Multidimensional scaling procedures place stimuli onto a spatial map so that stimuli which are rated as perceptually similar for a given characteristic are located closer together, whilst those perceived as different are located further apart (Kruskal and Wish 1978). Multidimensional scaling techniques are particularly well-suited to the study of complex sensory stimuli whose underlying dimensions and influencing factors are uncertain (Schiffman et al 1981), thus making it particularly appropriate in the study of sensory responses to fats.

Gender and Age

Since previous research has not explicitly addressed human ability to ascribe taste qualities to fats, the influence of the demographics of age and gender is unknown. Where gender is concerned, evidence has indicated that differences exist in the types of foods and dietary fat sources (Drewnowski 1995; Nestle et al 1998; Meiselman and Waterman 1978; Meiselman and Wyant 1984) and in self-reported food preferences (Drewnowski et al 1992; Drewnowski 1992; Nestle et al 1998). However no evidence has been found for gender-related differences in detection or hedonic rating for fat containing stimuli (Pangborn and Sacchetti 1984; Drewnowski et al 1989; Mela and Sacchetti 1991).

The influence of age upon sensory responses to dietary fat is even less clear. Previous research relating to aging has indicated that changes in taste may occur in conjunction with age-related taste deficits (Bartoshuk 1989; Weiffenback and Bartoshuk 1992) and some age-related differences have also been reported in hedonics and ability to detect fat in experimental stimuli (Warwick and Schiffman 1990; Schiffman et al 1992; Mela, Langley and Martin 1994). However, if age-related differences in taste responses to fat do exist, the occurrence and extent of this across the age span has yet to be established.

In order to examine the relationship between taste responses to fats and age and gender as fully as possible, both aggregated and multidimensional scaling techniques will be used. Therefore, for the purpose of the aggregated analyses, the following hypotheses have been generated:

Experimental Hypothesis 1: There will be a significant difference between males and females in their perception of primary taste qualities in fat stimuli

Experimental Hypothesis 2: There will be a significant difference between males and females in their perceived intensity of the taste of fats

Experimental Hypothesis 3: There will be a significant difference between males and females in their preference for the taste of fats

Experimental Hypothesis 4: there will be a significant difference between males and females in their preference for the texture of fats

Experimental Hypothesis 5: There will be a significant relationship between age and perception of the primary taste qualities in the fat stimuli

Experimental Hypothesis 6: There will be a significant relationship between age and perceived intensity of the taste of the fat stimuli

Experimental Hypothesis 7: There will be a significant relationship between age and preference for the taste of fat stimuli

Experimental Hypothesis 8: There will be a significant relationship between age and preference for the texture of fat stimuli

Method

Design

This study employed a between subjects design. Independent variables were age and gender. Dependent variables were taste responses to fats.

Participants

As described in Study 1, which focuses upon the same participant group, 83 participants were recruited: 64 females and 19 males. Participant ages ranged from 16 - 70 years old and the mean age was 28 years, with a standard deviation of 13.46. 72% (n = 60) of participants were aged 16 – 35, 17% (n = 14) were aged 36 – 50 and 11% (n = 9) were aged 51 – 70 years. 92% (n = 76) of participants were self-reported non-smokers whilst 8% (n = 7) described themselves as smokers. All participants were naïve as to the purpose of the study.

Materials

Stimuli

Stimuli Sensory stimuli for this study consisted of samples of butter ("Moonraker" St Ivel LTD, Swindon, UK), sunflower oil (J. Sainsbury plc, London, UK), corn oil (J. Sainsbury plc, London, UK) and walnut oil (J. Sainsbury plc, London, UK). The fats were stored in a cool, dark environment, in order to minimse interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

Questionnaires

In order to rate the perceived taste qualities and preferences for each sample of fat, participants completed response sheets (see appendix 1), containing 100mm line scales on which they indicated their rating of the stimuli's sweetness, saltiness, sourness, bitterness and liking for taste and texture (all anchored "not at all" and "extremely") and perceived flavour strength (anchored "barely detectable" and "strongest imaginable").

Procedure

Upon recruitment for this study, participants were requested not to smoke, clean their teeth, eat or drink anything except water for 2 hours prior to the study to minimise the risk that their taste perception of the fats would be contaminated. The 4 samples of fat; butter, sunflower oil, corn oil and walnut oil, were presented in small opaque plastic cups, each containing 10ml of the fat stimuli. Plastic spoons were provided for the tasting of the butter. The fats were evaluated separately and presented in a random order and participants were unaware as to the identity of each sample. A standard "sip-and-spit" procedure was employed, in which, after tasting, participants were required to expectorate and complete the relevant sensory rating scales. They were then required to rinse three times with distilled water, spitting out each time, before repeating this procedure with the next sample. Participants were required to take a 5 minute break between tasting and evaluating each fat sample. This was a recommended time needed to prevent the flavours of the sample being tasted being suppressed by those of the previous sample (Nguyen and Pokorny 1998). Age and gender of each participant was recorded.

Analysis

Independent t-tests were carried out to examine whether any significant differences could be found between males and females in their perceived sweetness, saltiness, sourness, bitterness or intensity of the fats and in rated taste and texture preferences. Pearson's correlations were carried out between age and rated taste responses to each fat.

Internal preference mapping, using MDPREF (Chang and Carroll 1968, PC-MDS), was also applied to the taste response data. MDPREF was principally designed to analyse individual preferences. However, given that in this study participants also rated taste qualities and intensity of fats using the same 100mm line scale used for rating preference these responses were also mapped onto the MDPREF solution to provide a full picture of individuals taste responses to the fat stimuli. MDPREF has previously been described as suitable for use with scores of acceptance or some other appropriate measure as long as all respondents have assessed all products and generated scores (Greenhoff and MacFie 1994). Visual inspection and interpretation was then applied to the MDPREF map and the solution was divided into quadrants providing different subgroups of participants relating to their taste response (Greenhoff and MacFie 1994).

Having segmented the participants according to their similarity in preference and taste responses, further observation established the sensory responses characteristic to each sub-group. Chi-square analysis was carried out to investigate the relationship between gender and the specific subgroups, whilst ANOVA was applied to establish any age difference.

Results

Aggregated Results

Gender

Mean taste responses to fat stimuli given by males and females can be seen in *Table 2.*

Table 2: Mean ratings for the presence of primary taste qualities, taste and texture preference and perceived intensity of fat samples given by males and females:

			Sweet	Salty	Sour	Bitter	Intensity	Taste Preference	Texture Preference
Corn Oil	Male	Mean	21.16	16.89	20.95	15.84	29.63	19.52	28.37
		±	24.60	21.70	24.41	17.66	22.62	17.13	26.00
	Female	Mean	18.42	16.11	15.11	17.69	29.72	16.09	20.84
		±	23.02	18.00	21.56	23.04	25.18	17.50	19.35
Walnut Oil	Male	Mean	19.74	28.57	31.16	29.16	56.89	32.68	34.00
		±	21.62	26.84	31.18	28.53	20.42	24.12	26.87
	Female	Mean	20.93	27.95	24.08	25.42	52.20	15.20	18.29
		±	20.99	25.87	27.92	27.40	22.33	18.38	17.34
Sunflower Oil	Male	Mean	22.74	16.26	21.21	21.32	21.84	24.63	23.63
		±	26.85	22.21	23.51	26.94	19.86	18.82	16.17
	Female	Mean	17.19	16.83	20.88	21.42	30.45	14.66	18.75
		±	19.06	20.24	23.98	25.30	25.15	16.42	19.44
Butter	Male	Mean	32.84	55.21	21.58	15.42	59.42	41.89	43.37
		±	26.71	23.43	20.99	16.67	18.13	20.36	18.70
	Female	Mean	34.05	55.14	15.59	13.41	61.58	45.23	43.58
		±	29.71	22.69	19.71	18.46	21.67	26.91	26.85

Independent t-tests revealed no significant differences between male and female respondents in their perceived sweetness, saltiness, sourness, bitterness or intensity of any of the fats. As shown in *Table 2*, males tended to prefer the taste of the three oils in comparison to females, whilst females gave greater hedonic ratings for butter than males. However, with Bonferroni's correction for multiple comparisons, independent t-tests only revealed statistically significant differences for walnut oil, $t(81) = 3.379$, $p<0.05$. Mean values in *Table 2* also indicate that males tended to prefer the texture of the three oils more than females. However, with Bonferroni's correction for multiple comparisons, independent t-tests revealed a statistically significant difference only for walnut oil, $t(81) = 3.026$, $p<0.05$.

Age

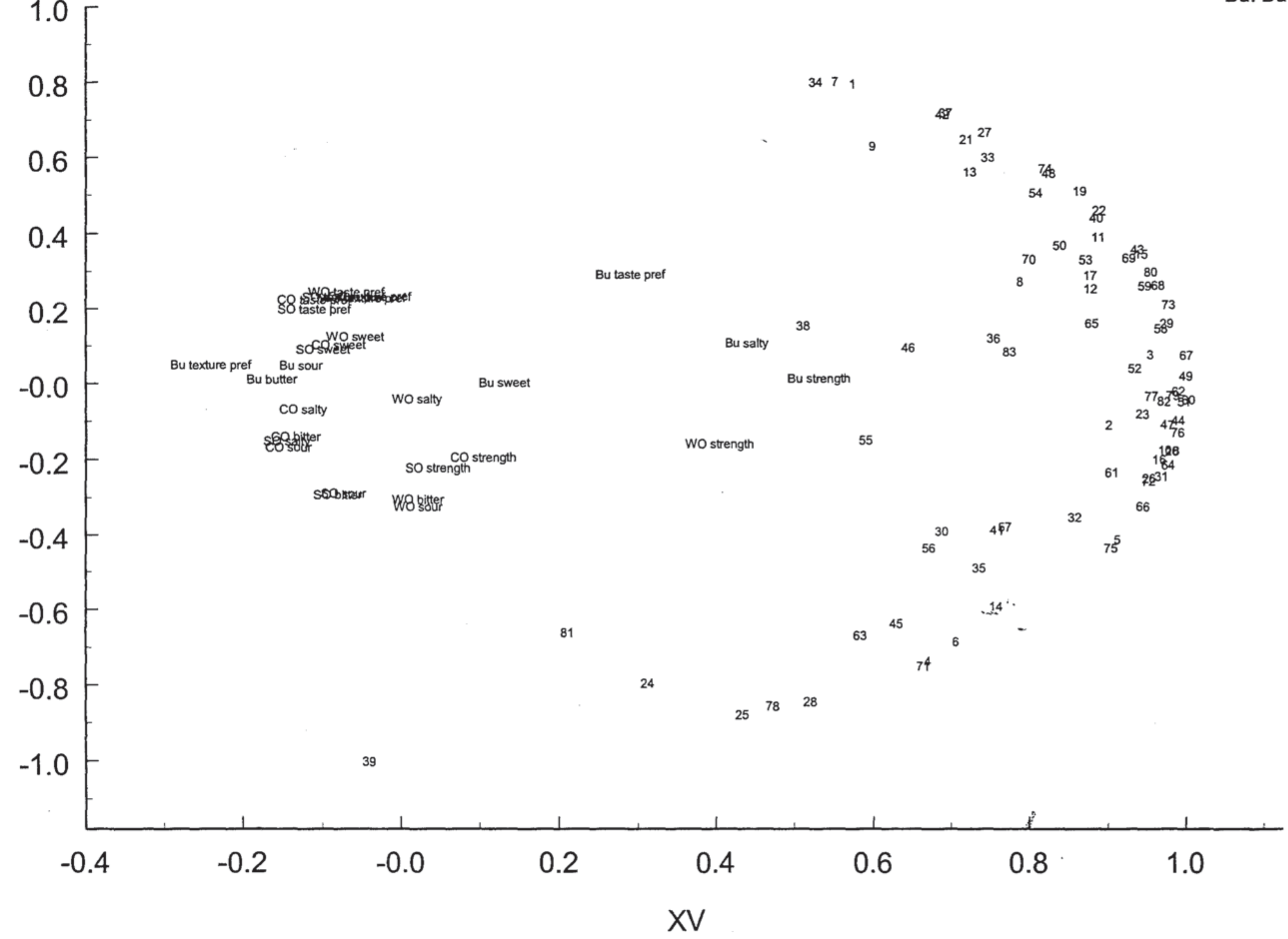
Pearson's correlation analysis indicated no significant relationship between age and perceived sweetness, saltiness, sourness, bitterness or intensity of any of the fats. However, small but statistically significant positive correlations were found between age and taste and texture preferences, as shown in *Table 3*.

Table 3: Pearson's correlations between age and taste and texture preferences for fats

	Taste Preference	Texture Preference
Corn Oil	$r = 0.38$, $p<0.01$	$r = 0.33$, $p<0.01$
Walnut Oil	$r = 0.38$, $p<0.01$	$r = 0.29$, $p<0.01$
Sunflower Oil	$r = 0.37$, $p<0.01$	$r = 0.32$, $p<0.01$
Butter	$r = 0.24$, $p<0.05$	$r = 0.27$, $p<0.05$

Figure 1: MDPREF solution illustrating individual taste responses to fat stimuli

CO: Corn oil
WO: Walnut oil
SO: Sunflower oil
Bu: Butter



MDPREF Analysis

The two-dimensional MDPREF solution is shown in *Figure 1* on the previous page. 49% of variance is accounted for by a two-dimensional solution. 36% accounted for by the first dimension and 13% accounted for by the second. The numbers around the configuration represent the ends of the assessors' vectors where a given rating was greatest. The vectors can be visualised by drawing a line from each point through the origin of the plot. The majority of participants vectors end at the right side of the plot indicating that butter was the most preferred fat sample, whilst the least liked were the oil samples which were also given similar hedonic ratings, hence their close proximity to each other on the plot. The solution also indicates that butter and walnut oil and perceived to be the most intense tasting of the fat samples, whilst sunflower and corn oils are rated as being less intense and similar in their strength. Further examination of the MDPREF solution illustrates that, where assessors have rated sourness and bitterness of each given fat sample, these two taste qualities are as plotted as perceptually very similar. The 3 oil samples also appear to have been judged relatively similar for the taste quality of sweetness.

From examination of the MDPREF plot it is clear that the respondent sample is not homogenous in its opinion of preference for the taste and texture of the fats or in its rating of the presence of particular taste qualities in the fat samples. No definite clear divisions can be made in perceptual space between clusters of respondents. However, looking at *Figure 1,* respondents in the top right quadrant (referred to as Subgroup 1) appear to be characterised by slightly sweeter taste responses to the fats, decreased detection of saltiness, sourness and bitterness and elevated taste preferences for the fat samples overall and particularly butter. The bottom right quadrant (referred to as

Subgroup 2) have the opposite view of the fat stimuli and are also characterised by perceiving greater intensity in the taste and flavour of the oil samples.

Having divided the plot into quadrants (with the centre point being 0.0:0.0) according to similarity of preference and sensory responses, analysis was carried out to see if it was possible to identify either subgroup with specific age or gender-related characteristics. It was found that 48% of respondents fell into Subgroup 1, whilst 51% fell into Subgroup 2. There was 1 outlier, which was removed from the analysis.

Gender

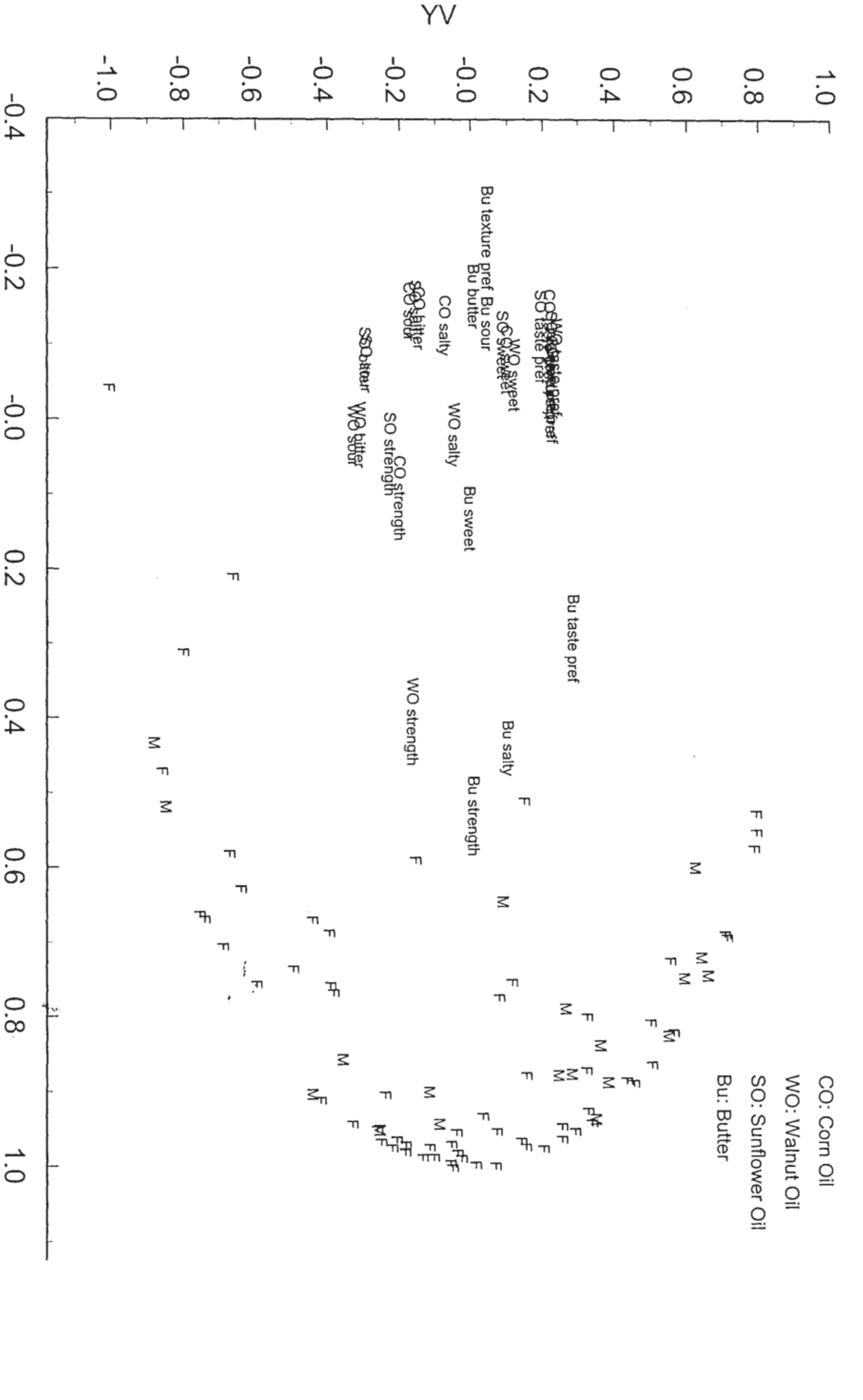
The numbers of males and female respondents who fell into each subgroup can be see in *Table 4*:

Table 4: Gender of respondents within taste response subgroups

	Subgroup 1	Subgroup 2	Total
Female	28	35	63
% of females	44.4%	55.6%	100%
% of total	34.1%	42.7%	76.8%
Male	12	7	19
% of males	63.2%	36.8%	100%
% of total	14.6%	8.5%	23.2%

This is also illustrated by *Figure 2* overleaf which shows the taste responses of males and females as revealed by the MDPREF solution.

Figure 2: MDPREF solution illustrating males and females taste responses to fats



As can be seen in *Table 4,* proportionally more females fell into Subgroup 2, whilst the opposite was the case for males. Chi Square analysis was applied to investigate whether there was any statistical association between gender respondent subgroup characterised by taste responses to fat. Analysis revealed that the assumptions for Chi square test were met. $X^2(1) = 2.046$, $p=0.153$, indicating a non-significant relationship between gender and taste response subgroup.

Age

The mean age within Subgroup 1 was 32 years (standard deviation 14.51), whilst the mean age within Subgroup 2 was 25 years (standard deviation 11.89). One-way ANOVA was applied to examine whether there was a statistically significant difference between the mean ages of the subgroups. Levene's test of homogeneity of variance indicated that this assumption had not been violated and therefore that the ANOVA statistics could be accepted. The result indicated that there was a significant difference between the mean ages in Subgroups 1 and 2, with Subgroup 1 containing a significantly older age group than Subgroup 2, $F(1, 80) = 4.644$, $p<0.05$.

Discussion

MDPREF Analysis

The MDPREF solution plot generated by this study indicates that the respondent sample were not homogenous in their opinion of preference for the taste and texture of the fats or in their rating of the presence of particular taste qualities of the fat samples. This would appear to suggest that individual variation does exist in human taste responses to fat. This in turn, may place into question the conventional wisdom that no flavour qualities can be perceived in fat and indicate that Gilbertson's (1997; 1998) findings regarding the ability of rat's to respond to taste qualities in fats may be of relevance to humans. It is of particular interest to note that the oil samples are all located with close proximity on the MDPREF solution map, which could suggest that any taste variations between oil stimuli due to their individual derivative ingredients may be less important than their similarities as a result of being a pure fat. This could provide some indication of a unique taste response to fat and a specific "fatty" taste quality.

By comparison, the MDPREF map indicated that taste responses to butter had little resemblance to responses to the oil stimuli. As was discussed previously in chapter 3, this is likely to be related to the fact that commercially produced butter contains more additional additives than oils, including salt as a major component. Therefore the taste qualities perceived in the butter cannot be completely attributed to the fat component of the stimulus and butter cannot truly be directly compared to oils as a form of fat.

The division of respondents into two subgroups according to their placement on the MDPREF map is somewhat questionable in that individuals are not placed in separate and clearly defined clusters. However, this technique has been used to similar effect in previous published research using MDPREF analysis (Greenhoff and McFie 1994) and within this study proved a useful tool in characterising individuals according to their perceptual space. Equally the fact that multidimensional scaling is an exploratory tool as opposed to a stringent hypothesis testing method makes this more acceptable and appropriate.

By dividing the respondents into two subgroups, it appears that Subgroup 2 could basically be characterised by greater perception of saltiness, sourness and bitterness in the oil stimuli, whilst Subgroup 1 perceived the oils to be sweeter tasting. Subgroup1 was also characterised by greater preference for both the taste and texture of the oils. This could be linked the fact that they perceived enhanced sweetness, which is frequently regarded as a more desirable taste quality or may equally be related to the fact that they rated the overall taste of the fats as being less intense than Subgroup 2. The latter hypothesis can be related to Gilbertson's (1998) finding that rats with elevated sensitivity to fats showed decreased preference.

The use of primary taste qualities as descriptors for the fat stimuli was also employed in Study 1 (described in chapter 3) and potential disadvantages with this method were identified. As was previously stated, tastes elicited by fats are both complex and subtle and are unlikely to be fully and adequately explained by requesting forced-choices response ratings of the four primary taste qualities. One advantage to selecting the use of primary taste qualities as descriptors was the assumption that these qualities are widely and consistently recognised, thus minimising the risk of variation as a result of differing interpretation of taste labels. However the very close proximity of the labels “bitter” and “sour” on the MDPREF map for each oil sample suggests that respondents may have considered these taste qualities to be almost identical in sensation. Providing baseline samples of substances, such as sucrose or quinine, which are known to have definite sweet, salty, sour or bitter taste qualities would have been a means of definitely establishing individual’s interpretation of the taste quality labels.

The use of multidimensional scaling as an analysis tool in this study brings with it a number of advantages and weaknesses. MDPREF is clearly an exploratory technique, as opposed to a hypothesis-testing tool, therefore the interpretation of the solution plot, and particularly its division into subgroups, may be seen as subjective and questionable. However, the exploratory nature of the technique also brings with it the advantage of highlighting attributes which may be worthy of further research in areas where little study has been carried out and underlying dimensions are uncertain. Hypotheses may then be generated which can be more stringently tested in further research. This is particularly pertinent in this study, given the lack of previous research in this specific area.

The display power of multidimensional scaling is a particular strength in that by generating solution plots it provides visualisation of complex sensory data. However it must be taken into account that the perceptual map is a mathematical solution, not an actual pictorial representations of what was occurring in the respondents’ minds. However possibly the most important advantage of using multidimensional scaling in this study is the fact that it allows acceptance ratings and taste quality responses to be viewed at an individual level, thus demonstrating individual variation in taste responses to fats in a way that the aggregated analyses methods used in Chapter 3 failed to do.

Exploration of multidimensional scaling techniques has indicated that the validity of the solution relies greatly upon the quality of the data, as the tool does not make allowances for product variation (Greenhoff and McFie 1994). Therefore any property differences between a given fat type within this study would reduce the validity and value of the MDPREF map. However, measures were taken to minimise the risk of any inter-product variation by taking care to store fat stimuli in appropriate environmental conditions, as was fully discussed in chapter 3. Equally, as has also been previously stated, research indicates that changes and rancidity in fats was hardly perceived by trained assessors unless oxidation had occurred to a high degree, such as after frying (Nguyen and Pokorny 1998). This suggest that it is reasonably safe to discount variation in stimulus qualities as a contributory factor to the individual differences in response illustrated in the MDPREF solution.

One possible improvement which could have been made to this study in order to further establish the reproducibility and robustness of the MDPREF map would be to replicate a proportion of the fat samples. This would indicate the reliability of the solution by showing how closely identical samples were placed together on the map. However, as was discussed earlier, the fact that the oil stimuli are all located within close proximity does in itself indicate reliable and consistent taste responses.

Gender

The findings of this study suggested that, when aggregating data across all individuals, no significant gender-related differences were found in perceived sweetness, saltiness, sourness, bitterness or intensity of fat samples. However significant differences were found between males and females in their hedonic responses to the taste and texture of fat stimuli. The overall trend of the aggregated data indicated that males demonstrated a greater preference for the taste of the three oil samples, whilst females had a slightly elevated taste preference for butter. However these differences were only statistically significant in the case of walnut oil. Males also demonstrated an increased preference for the texture of the oils but again this was only statistically significant for walnut oil.

On the basis of these aggregated findings, hypothesis 1, stating that "*there will be a significant difference between males and females in their perception of primary taste qualities in fat stimuli*," and hypothesis 2, stating that "*there will be a significant difference between males and females in their perceived intensity of the taste of fats*" are both rejected. However, hypothesis 3, stating, "*there will be a significant difference between males and females in their preference for the taste of fats*" can be partially accepted in the cases of walnut oil and sunflower oil. Hypothesis 4 stating, "*there will be a significant difference between males and females in their preference for the texture of fats*" can also be accepted for walnut oil.

Overall, these aggregated findings indicate that, whilst the level of its contribution is questionable, gender does appear to have some influence over differences in preference for the taste of fats, with males demonstrating elevated preference for oils whilst females gave higher hedonic ratings for butter. Caution must be exercised in accepting these findings as the data revealed statistical significance only for sunflower and walnut oils. However these results are still in contrast to previous studies which have indicated that no gender distinction could be found in hedonic rating of differing levels of fat in sweetened liquid dairy products (Pangborn and Sacchetti 1984; Drewnowski et al 1989; Mela and Sacchetti 1991). This difference could easily be attributed to the use of pure processed oils in this study as opposed to sweetened dairy-based stimuli.

When the relationship between gender and taste responses to the fat samples was examined using the MDPREF solution map it was possible to gain a more detailed view. A higher percentage of males were found to be concentrated in the area of the map labelled Subgroup 1 (63.2%), whilst the opposite trend was found for females, although they were also more evenly split (44.4% in Subgroup 1, 55.6% in Subgroup 2). However Chi square analysis revealed these differences to be non-significant.

The MDPREF solution gave a different perspective from the aggregated analysis with regard to gender-related distinctions in taste preference for the fat samples. Subgroup 1 was characterised by elevated preference for all four fat stimuli. As stated previously it also included a higher percentage of males than Subgroup 2. However the map also revealed large numbers of females within Subgroup 1, suggesting that gender was not an important contributor to individual differences in preference.

As discussed previously, studies have indicated that differences exist both in the types of food which males and females choose to consume and in their chief sources of dietary fat. Females have been found both to select and prefer sweet sources of fat such as deserts and ice cream and dairy based products (Drewnowski 1995; Nestle et al 1998). In contrast, males tend to list more savoury fat sources such as meats and pizza and fried foods such as chips as both their main sources of dietary fat and the foods they most enjoy eating. Interestingly, these findings can be seen as partially reflected in the individual responses of males as mapped onto the MDPREF solution. Males were more highly concentrated in Subgroup 1 which was characterised by increased preference and tolerance for the taste and texture of oils, something which would be expected if participants more regularly consumed fried foods where oil is a noticeable aspect of the food matrix.

Subgroup 1 was also characterised by decreased perception of the intensity of the taste of the fat samples and by an elevated perception of sweetness. It could be hypothesised that this may also relate to gender-related dietary characteristics. However in order to establish this with any degree of reliability sensory responses to fats would need to be related to reliable information regarding individuals dietary intakes and preferences, as opposed to generalising aggregated findings from previous studies concerning gender and diet.

One of the main difficulties in attempting to interpret gender-related findings is the need to account for the imbalance between the numbers of males and females recruited for this study. Had more data been available from male respondents it may have been that more obvious gender-related patterns or clusters may have become apparent within the MDPREF solution. This could also account for the failure to find statistically significant results within the aggregated analyses.

As suggested by previously discussed research, gender-related differences do appear to exist in both dietary fat intake and preferences for the source of dietary fat. However, it would appear that this is less likely to be a function of gender differences in the fundamental taste qualities of fat and more likely to be influenced by factors such as attitudes, health beliefs and weight concerns which may differ between males and females. Sensory response to fat is a subtle and complicated issue and attempting to explain this by gender appears overtly simplistic, particularly when taking into account the numerous individual characteristics people have, whether male or female.

Age

The aggregated results of this study indicated that no significant correlational relationship existed between participant's age and their perception of sweetness, saltiness, sourness, bitterness or intensity of any of the fat samples tasted. Therefore hypothesis 5, stating that "*there will be a significant relationship between age and perception of the primary taste qualities in the fat stimuli,*" and hypothesis 6, stating, "*there will be a significant relationship between age and perceived intensity of the taste of the fat stimuli*" are both rejected.

However aggregated results did reveal small but statistically significant positive correlations between age and taste and texture preferences for each of the fat stimuli. Thus hypothesis 7, stating that "*there will be a significant relationship between age and preference for the taste of fat stimuli*" and hypothesis 8, stating, "*there will be a significant relationship between age and preference for the texture of fat stimuli*" are both accepted.

As with gender, more individual-based information regarding age and taste responses to fats can be gained by examining the MDPREF solution. ANOVA revealed that Subgroup 1 was characterised by a significantly older mean age of respondent (32 years) than Subgroup 2 (25 years). As has been discussed previously, Subgroup 1 was generally characterised by greater preference for the taste and texture of fats and lower perception of primary taste qualities and intensity. More detailed examination of individual respondents also revealed that those aged 30+ tended to be plotted onto the MDPREF map in perceptual space characterised by lower perception of taste intensity.

The fact that the older age group in this study seem to have lower perception gives support to findings from previous research suggesting that older adults have a reduced ability to detect fat accurately and increased discrimination thresholds for fats (Mela, Langley and Martin 1994: Schiffman et al 1992), thus pointing to a reduction in taste acuity. This in turn could also help to explain their increased preference for the fats, although potential age-related dietary differences and attitudes cannot also be ruled out. Whilst this study supports previous research in suggesting that increased age leads to decreased sensitivity to fats, the MDPREF solution also proposes very preliminary evidence that there may also be an inverse relationship between age and the ability to detect basic taste qualities in fat. However, it must be taken into account that correlational analysis failed to demonstrate this as significant, suggesting the decline in perception is very slight and therefore open to question.

Whilst the ages of participants in this study ranged from 18-70 years, 67% of these were under the age of 30 years. Previous research has yet to establish whether age related decline in taste sensitivity is a continuous phenomenon or something that may begin to occur around a particular given age. Mela, Langley and Martin (1994) noted age-related decrease in sensitivity to fat in participants as young as 30, something which appears to be supported by the MDPREF solution in this study. However this has yet to be reliably established and other studies have placed age-related taste declines at much later life stages (i.e. Warwick and Schiffman 1990; Schiffman et al 1992). If the latter were the case then more older respondents would be required than were recruited for this study.

Conclusion

The findings of this study drawn from MDPREF analysis build upon the results of the previous study described in chapter 3 in indicating that individuals are able to detect the presence of primary taste qualities in fats. However the results of this study also suggest that individual variation exists in the types and intensity of taste qualities detected, as well as in hedonic response to fats. This suggests that further research is needed to examine underlying factors and causes for this variation. The results of the present study would suggest that, whilst age and gender do appear to play a role in influencing taste responses to fat, the relationship with both of these demographic characteristics failed to be fully consistent.

Chapter 5

How do individuals describe the taste of oils using Free Choice Profiling?

Study 3

Introduction

The findings of studies 1 and 2, drawn from both aggregated data analysis and multidimensional scaling techniques, provided some indication that individuals are able to describe the taste of basic fats using the primary taste descriptors of sweet, salty, sour and bitter. However, as has been discussed within these studies, pure fats are subtle and complex taste stimuli and the use of the four primary taste labels is a relatively simplistic method. Therefore this may fail to provide an adequate portrayal of individuals' true taste responses. The method of enforcing potential taste descriptors upon respondents may also mask individual differences by not allowing them to express their own sensory responses.

The aim of this study was to investigate whether participants were able to describe the taste of pure processed oils using their own individually generated taste descriptors. Thus the multivariate sensory technique of Free Choice Profiling was employed. Free Choice Profiling makes the assumption that, whilst individual's may not necessarily differ in the types of sensory characteristics they perceive within a given stimulus, they are likely to differ in the way in which they label these (Guy, Piggott and Marie 1989). Therefore Free Choice Profiling allows assessors to develop their own individual descriptive vocabulary and use this to score a set of samples (Williams and Arnold 1985). This means that, in theory, the potential problem discussed in the previous two studies of individuals having incorrect or different understandings of the enforced taste labels should no longer exist.

Free Choice profiling has proved a valid and reliable technique in the study of a wide variety of products (i.e. Williams and Langron 1984; Williams and Arnold 1985; Guy, Piggott and Marie 1989; Li et al 1997), using both trained expert panels and consumer respondents (Guy, Piggott and Marie 1989). Its validity requires that respondents are able to follow basic training instructions, be objective, be capable of using sensory scales and use the developed vocabulary consistently (Williams and Langron 1984). Therefore, it was deemed to be an appropriate method to use with a university-recruited population for this study. A relatively large sample of 31 participants was also recruited, as opposed to smaller trained samples (approximately 15 participants) described in previous published research using Free Choice Profiling, to increase the reliability and stability of the results (Guy, Piggott and Marie 1989).

A further aim of this study was to examine whether specific taste components could be identified with differing types of fat or whether there existed a consistent taste profile across all samples. In order to build further upon the evidence gained from the previous two studies, a larger number of varying pure processed oil samples was used for this study. The use of butter was also eliminated due to the factors discussed in the previous studies regarding its non-comparability with pure processed oils. Replicated samples of olive oil and walnut oil were included as a measure of reliability and consistency. These specific samples were selected due to the fact that they represent both a relatively strong tasting oil stimuli (walnut) and a more subtle sample (olive).

Method

Design

This study employed a multivariate exploratory design, using the technique of Free Choice Profiling to allow individuals to generate their own taste descriptors for oils.

Participants

31 participants were recruited for this study aged between 18 – 35 years in an attempt to minimise age-related differences in taste responses to fats. All participants were female to control for gender-related differences. 23% (n = 7) were self-reported smokers whilst 77 (n = 21) were non-smokers.

Materials

Stimuli

Fat stimuli for this study consisted of samples of olive oil (J. Sainsbury plc, London, UK), sunflower oil (J. Sainsbury plc, London, UK), corn oil, (J. Sainsbury plc, London, UK), walnut oil (J. Sainsbury plc, London, UK) and sesame oil (J. Sainsbury plc, London, UK). As in previous studies, the fats were stored in a cool, dark environment, in order to minimise interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

Questionnaires

During the initial phase of the study participants were provided with paper on which to record the list of personal taste qualities they perceived in the oil samples. These taste characteristics were then transferred to response sheets containing 100mm line scales (anchored "not at all" and "extremely"), which were used to rate the intensity of each taste quality for each oil sample (see appendix 2). Participants also used 100mm line scales to record their liking for taste and texture (all anchored "not at all" and "extremely") and perceived intensity (anchored "barely detectable" and "strongest imaginable").

Procedure

The study took place over 2 separate sessions. Upon recruitment participants were requested not to smoke, clean their teeth, eat or drink anything except water for 2 hours prior to each session to minimise the risk that their taste perception would be contaminated.

During the first session participants were presented with a training example of Free Choice Profiling in the form of an extract describing taste characteristics generated to describe the taste of port (Williams and Langron 1984) (see appendix 2). Participants were then presented with the 5 samples of oil and requested to taste each sample as required and generate a list of all the terms needed to evaluate the taste of the oils. The oils were tasted using a standard "sip-and-spit" procedure. Distilled water was also provided and participants were required to rinse with water between samples until they felt traces of the previous oil sample had been removed.

During the second session participants tasted and evaluated each oil sample in a random sequence using 100mm line scales identified with their own list of taste terms. Olive oil and walnut oil samples were presented twice to test for reliability and consistency in ratings. Again a standard "sip-and spit" procedure was applied and participants were required to rinse three times with distilled water, spitting out each time, before repeating this procedure with the next sample. Participants were also required to take a 5-minute break between tasting and evaluating each fat sample. This was a recommended time needed to prevent the flavours of the sample being tasted being suppressed by those of the previous sample (Nguyen and Pokorny 1998).

Analysis

Principal components analysis was applied to each attribute scored by each individual for each oil sample. This was done by creating a data sheet on which oil stimuli identified the rows and attributes scored by each assessor formed columns. Principal components analysis then allowed overall consensus scores to be generated for each demonstrating how strongly each oil sample loaded onto descriptors generated by each assessor. This allowed factors to be extracted which were characterised by similar taste descriptors and provided information on the taste qualities perceived as characterising specific fat samples.

Results

31 participants scored each oil sample using their own individually generated descriptor terms. Taste descriptors generated by each participant can be seen in *Table 5*:

Table 5: Taste descriptors for oil stimuli generated by each participant

Participant	Taste descriptors
1	Woody, sticky, sour, stale, nutty, strong, harsh, watery
2	Smoked, plastic, burnt, fatty, dirty, plain, light, chemical
3	Grease, peanuts, bitter, nutty
4	Toast, buttery, fried, burnt, nuts, salty
5	Sticky, burnt, roasted, almond, smoky, plastic, fish, buttery, cooked
6	Nutty, fish, burnt, peanuts, plain, margarine, cream
7	Nutty, sweet, light, watery
8	Gloopy, grease, burnt, nutty, salty
9	Mustard, nutty, coffee, burnt, toast, salty
10	Dark, fatty, nutty, buttery
11	Salty, buttery, fatty, nutty, roasted, bitter, rich, harsh
12	Grease, smoky, bitter, nutty, roasted, fatty, coffee, toasty, earthy
13	Fatty, butter, chocolate, burnt, cream, nutty, vanilla
14	Fatty, nutty, cardboard, burnt, tobacco, smoky
15	Fatty, bitter, dirty, nuts
16	Almond, coffee, ash, dark chocolate, fatty, nuts, roasted, burnt

Participant	Taste descriptors
17	Fatty, nutty, woody, roasted, plastic, smoky, bitter
18	Peanuts
19	Fatty, butter, burnt, roasted, water, vanilla, tangy, smoky, almond
20	Cream, nutty, woody, almonds, smoky, sweet, acidic, burnt
21	Nutty, meat, bitter, smoky, earthy, rich, butter, burnt, crisps, salty, vanilla
22	Dry, fishy, sour, nutty, butter, burnt, toast, salty
23	Nutty, sweet, cooked, almond, roasted, sour, bitter, woody, smoky, butter, coffee
24	Nutty, earthy, almond, sweet, peanut, fatty, coconut, sugary, rich, coffee
25	Nutty, dry, sticky, coffee, woody, fatty
26	Fatty, almond, coffee, plain, flour, peanut, salty
27	Honey, peanuts, sweet, cashew, nuts
28	Fatty, cardboard, nutty, smoky
29	Bitter, fatty, cream, burnt, sharp
30	Plastic, nutty, vanilla, walnut
31	Nutty, bitter, fatty, coffee, plastic, burnt, dry, plain

Principal components analysis was applied to each attribute scored by each individual for each of the oil samples. The determinant exceeded the necessary value, indicating that multicollinearity was not a problem. A varimax rotation method was also applied, with Kaiser normalization, to maximise the dispersion of loadings within each factor. The rotation converged in 8 iterations. The final rotated solution indicated that 85.6% of variance could be explained by the first 4 factors extracted. Factor 1 accounted for 38.2% of variance, Factor2 for 19.6% of variance, Factor 3 for 15.7% of variance and Factor 4 for 12.1% of variance. The important taste responses from each participant, which loaded highly onto each of the 4 factors, and their respective loadings are shown in *Table 6*:

Table 6: Taste qualities loading highly onto the 4 factors extracted

Factors			
1 (Smoky, bitter, burnt)	2 (Salty, peanutty)	3 (Almondy, nutty, sweet)	4 (Fried, oily, greasy, fatty)
Woody 0.816	Smoked 0.967	Stale 0.841	Bitter 0.926
Plastic –0.852	Burnt 0.968	Harsh 0.843	Fried 0.720
Plain –0.735	Peanuts 0.774	Watery –0.860	Gloopy 0.847
Chemical 0.934	Nuts 0.958	Grease 0.881	Grease 0.887
Burnt 0.881	Salty 0.890	Burnt 0.725	Mustard 0.984
Fish 0.888	Nutty 0.720	Roasted 0.742	Nutty 0.795
Light 0.810	Salty 0.968	Almond 0.853	Buttery 0.701
Coffee 0.914	Nutty 0.740	Smoky 0.773	Rich 0.879
Burnt 0.920	Grease –0.894	Cooked 0.752	Nutty 0.852
Toast 0.965	Nutty 0.962	Nutty 0.830	Woody 0.841
Smoky 0.904	Roasted 0.920	Sweet 0.759	Cooked 0.738
Fatty –0.965	Fatty –0.912	Salty 0.785	Woody 0.874
Cardboard –0.946	Coffee 0.974	Bitter 0.830	Fatty 0.703
Burnt 0.893	Toasty 0.911	Fatty –0.730	Burnt 0.714
Tobacco 0.723	Chocolate 0.954	Salty 0.804	Plasticy 0.894
Coffee 0.898	Burnt 0.981	Sweet 0.743	
Ash 0.866	Cream –0.944	Sugary 0.865	
Dark chocolate 0.928	Nutty 0.949	Nutty 0.720	
Water –0.755	Dirty 0.889	Cream –0.927	
Bitter 0.980	Nuts 0.882	Nutty 0.842	
Burnt 0.755	Cream -0.887	Bitter 0.821	
Dry 0.725	Sweet 0.873	Plain –0.865	
Roasted 0.737	Acidic 0.931		
Nutty 0.709	Smoky –0.727		
Peanut 0.827	Fishy 0.969		
Coffee 0.920	Earthy 0.775		
Plain –0.889	Rich –0.844		
Nutty 0.875	Peanut 0.913		
Bitter 0.846	Salty 0.936		
Nutty 0.825	Peanuts 0.842		
	Cashew nuts 0.911		
	Fatty –0.938		

Table 6 illustrates that a number of taste qualities, such as nutty, are replicated across all 4 main factors. However, overall Factor 1 appears to be characterised by "smoky,

bitter, burnt" flavours whilst a strong negative loading is found with more neutral taste qualities such as plain and watery. Factor 2 seems to be associated with "salty, peanutty" taste properties, with a negative association with responses such as rich and fatty. Factor 3 is characterised by "almondy, nutty, sweet" tastes and shows negative loadings from taste rich and fatty responses and the neutral qualities of plain and watery. Factor 4 can be associated with "fried, oily, greasy, fatty" taste characteristics.

The association between each oil sample and each of the 4 factors was analysed using regression and is illustrated in *Table 7.* Replications of olive oil and walnut oil are shown:

Table 7: The factor scores between oil stimuli and each main factor

	Factor			
	1	2	3	4
Olive	-0.7369	-0.6187	1.2446	-0.4262
Sunflower	-0.7689	-0.0830	-1.6904	-1.2952
Corn	-0.8647	-0.2351	-0.6029	1.9870
Walnut	1.2998	-0.7110	-0.2279	0.1218
Sesame	0.1387	2.2089	0.3097	0.0158
Olive	-0.5275	-0.3591	1.0377	-0.4207
Walnut	1.4596	-0.2019	-0.0708	0.0176

Table 7 indicates that the association scores for the replicated samples of olive oil and walnut oil were relatively closely matched for each factor. This suggests that individual's responses for each fat sample were reliable and meaningful. A high

positive association can be seen between walnut oil samples and Factor 1, which is characterised by smoky, burnt and bitter qualities. Sesame oil was the only other sample to load positively onto this factor. Sesame oil is also the only sample to demonstrate a positive relationship with Factor 2, associated with salty, peanut-like tastes. Despite its nutty taste qualities, walnut oil had a relatively high negative association with this factor. Factor 3, characterised by almondy, nutty, sweet taste properties, was positively related to olive oil samples but negatively associated with all other oil stimuli. Corn oil demonstrated a fairly high positive correlation with Factor 4, which was associated with fried, oily, greasy and fatty taste qualities. Sesame oil and walnut oil samples also shared smaller positive relationships with factor 4, whilst sunflower oil and olive oils were both negatively associated.

Discussion

The findings of this study suggest that individuals are able to generate their own taste quality vocabulary and use this to describe the tastes of a wide range of pure processed oils. This builds upon the results of the previous two studies, by providing further indication that individuals can describe a taste component to fats and suggesting that this finding was not simply a reaction to the presence of forced-choice taste categories. The fact that, in this study, replicated oil samples demonstrated relatively similar responses even though participants were unaware of their identity, suggests that such taste quality labels were consistent, reliable and meaningful. It should also be taken into consideration that taste characteristics were rated using 100mm line scales, as opposed to discrete categories, therefore some discrepancy is likely to occur due to the possibility of varied placement on the line scale which is a key feature of this method.

The results of this study also suggested that pure processed oils appear to possess their own unique taste quality profiles depending upon the derivative of the oil, as opposed to the same taste characteristics accounting for oil samples overall. This can clearly be demonstrated by the statistical association each oil stimuli shares with the four main factors extracted from all taste descriptors, using principal components analysis. Factor 1, characterised mainly by smoky, burnt, bitter taste qualities, had a strong positive statistical relationship with walnut oil and a smaller positive association with sesame oil. Both of these oil stimuli can be regarded as fairly strong tasting due to their derivative components. Factor 2, associated overall with salty, peanutty flavours, was also strongly negatively associated with sesame oil. However, despite the fact that it is a nut-based oil, walnut oil shared a negative relationship with this factor. This suggests that these two oil stimuli still elicited varying taste responses despite their similarities and that respondents were able to discriminate fairly reliably between these.

Factor 3, which appeared to be characterised by almondy, nutty, sweeter taste qualities was positively associated with the more subtle-tasting olive oil. These taste labels could also be associated with more pleasant taste sensations than the first two factors which may be a reflection of the tendency to consume olive oil neat as a dressing for salads, etc, whereas this is done less frequently with the other oil samples used in this study. Finally, Factor 4 can be associated with fried, oily, greasy and fatty taste labels and has a strong positive relationship with corn oil. Positive statistical relationships are also found with walnut and sesame oil. All of these oil samples are most commonly used for frying and cooking purposes and these taste qualities may be a reflection this. However, surprisingly sunflower oil, which is also commonly used in this way and, like corn oil, is a relatively subtle tasting fat, shared a negative association with this factor.

The variation in taste characteristics between different oil samples can be meaningfully and logically explained. It also raises the possibility that individuals may be responding, at least in part, to the taste qualities of the oil derivatives, as opposed to the fat itself. To a certain extent this can be seen as an inevitable result of using commercially available oils as opposed to laboratory-produced pure fats. However, the latter cannot be seen as a true representation of the pure fats which individuals consume in their everyday lives. The fact labels such as fatty and oily were only positively associated with specific factors extracted suggests that these labels were taste and not textural descriptors. This could be seen as evidence suggestive of the possibility that pure fats may possess a subtle but unique fatty flavour and supports the suggestions by previous research that a fatty taste quality appears to be mediated in part by taste nerves (Gilbertson et al 1997; Schiffman 1997).

The use of Free Choice Profiling clearly carries with it the advantage of allowing participants to generate their own individually meaningful vocabulary of taste descriptors. Many of the taste qualities listed could be seen as fitting into and representative of the four primary taste quality categories of sweet, salty, sour and bitter. However, in allowing individuals to provide their own labels reliability and consistency appears to be increased. This technique also increases the richness of taste descriptor vocabulary and allows for the use of terms that are not clearly represented by the primary taste categories. For example, the use of terms such as watery and plain may represent participants who felt unable to detect any prominent taste qualities in particular fat samples. The use of Free Choice Profiling allows them to express this more freely and thus reduces the possibility that respondents will report taste qualities they did not truly perceive, which is a particularly pertinent issue in the study of stimuli such as fats, where the presence of taste properties is uncertain or subtle.

However, the use of Free Choice Profiling also carries with it difficulties. The advantage of individually generated descriptive vocabularies can be seen as at least partially offset by difficulties in interpretation due to the fact that the meaning of given terms cannot be definitively established. This is particularly the case when using comparatively larger numbers of respondents in this study and thus gaining a wider variation of terms. Yet, it could also be argued that the true meaning an individual holds of researcher enforced taste terms may be equally unclear and that such risks appear to be outweighed by the advantages of the method.

Due to the fact that Free Choice Profiling allows individuals to use differing terms to describe their perceived taste responses, comparison between individual responses is more problematic. The use of principal components analysis within this study allowed perceptual differences between the oil stimuli to be highlighted and investigated but in doing so further disguised any individual differences which may have existed within the data. Therefore this will be addressed in subsequent studies by investigating whether differing taste responses still exist when using taste labels based more closely upon individually generated descriptors and focusing upon further factors which may be related to these.

Chapter 6

The relationship between genetic PROP taster status and taste responses to oils and fat containing foods

Study 4

Introduction

A growing body of research has indicated that there may be an inherited component to individual differences in sensory responses to foods and that genetic variation in taste sensitivity to bitter thiourea compounds, such as 6-*n*-propylthiouracil (PROP) and phenylthiocarbamide (PTC), may be a marker for these (Bartoshuk, Duffy and Miller 1994; Drewnowski and Rock 1995; Tepper 1998). Given the nutritional significance of dietary lipids, the relationship between PROP/PTC bitterness and sensory perception of fats is of particular interest (Tepper and Ullrich 2002) and a series of studies have indicated an inverse relationship between sensitivity to PROP and preference for and sensitivity to fats and selected fat-containing foods (Duffy et al 1996; Tepper and Nurse 1997; Forrai and Bankovi 1984; Duffy, Weingarten and Bartoshuk 1995).

Previous published research has tended to focus solely upon hedonic ratings for fat-containing substances and foods and the perceived intensity of fat in stimuli such as salad dressing (Tepper and Nurse 1997) or dairy fluids (Drewnowski, Henderson and Barrett-Fornell 1998). Such studies have been carried out from the theoretical assumption that individual differences in fat perception as a function of PROP sensitivity are due to textural cues from the fat. However the relationship between detected bitterness in PROP and actual taste qualities perceived in pure processed fats has never actually been investigated by any previous published research. In particular, previously cited research by Gilbertson et al (1998) which concluded that polyunsaturated fatty acids had a greater effect upon the taste receptor cells of a fat-avoiding strain of rats, compared with a fat-preferring strain could be used to question the conventional view that PROP related differences in response to fats are due to textural cues alone. The fact that both the fat-avoiding strain of rats and PROP tasters have been shown to exhibit greater sensitivity to fats and decreased preference could be used to suggest that individual differences may also be present in the perceived taste qualities and flavour of fats as a function of PROP taster status. Equally, even if differences do not occur in the type of taste qualities detected within the fat, the fact that PROP tasters have been shown by some studies to have greater sensitivity to fats (i.e. Tepper and Nurse 1997) could lead to the expectation that they would perceive any taste qualities present in fat as being stronger than non-tasters.

Therefore, the main aim of this study was to examine the relationship between PROP taster status and taste qualities and preferences perceived in pure processed oils. Previous published research has used fat-containing stimuli, such as salad dressing (Tepper and Nurse 1997) and liquid dairy fluids (Drewnowski, Henderson and Barrett-Fornell 1998), where fat may be masked by the additional properties of the stimuli. Therefore this study aimed to establish sensory responses to pure processed oils. Corn oil and walnut oil, which have been established by Studies 1, 2 and 3 reported here, as having varying taste profiles as a function of their derivatives, were selected as taste stimuli. Due to the fact that no previous published research had focused upon this area and that earlier studies within this work had established it as a useful method, possible differences in the perception of the four basic taste qualities were deemed to be an appropriate technique. This could then be extended to the investigation of additional taste qualities and methods should differences appear to be present. Both aggregated analysis methods and multidimensional scaling were applied to provide the most thorough investigation and ensure that any individual differences were not masked.

As stated earlier, previous research has also indicated an inverse relationship between PROP taster status and preference for fat-containing foods. Specific foods found to have reduced acceptance by PROP/PTC sensitive individuals include whipped cream (Forrai and Bankovi 1984), ice cream, donuts, whole milk, mayonnaise, bacon and sausage (Duffy and Bartoshuk 2000). However it is clear that despite these findings of reduced acceptance for fat-containing foods, PROP tasters must still consume some dietary fat. Equally, fat-containing foods carry with them a wide variety of taste qualities and properties and previous published research has not examined whether specific categories of fat-containing foods are preferred or disliked more as a function of PROP taster status. Therefore, a further aim of this study was to investigate whether PROP sensitivity-related differences could be found in the type of fat-containing snack an individual reported preferring most. Given that PROP tasters appear to have enhanced sensitivity to fats it might be expected that they would be more likely to select a food type where fat is less obvious within the matrix of the food, i.e. biscuits as opposed to ice cream. However it is also possible that PROP taster status may determine liking for particular taste qualities, i.e. sweet as opposed to salty. If this were the case, these findings could then be related to the taste qualities individuals had reportedly perceived in pure processed oils in order to look for any relationship.

For the purpose of aggregated analyses, the following hypotheses were generated:

Experimental Hypothesis 1: There will be a significant difference between PROP tasters in their perception of primary taste qualities in pure processed oil stimuli

Experimental Hypothesis 2: There will be a significant difference between PROP tasters in their perceived intensity of pure processed oil stimuli

Experimental Hypothesis 3: There will be a significant difference between PROP tasters in their preferences for pure processed oil stimuli

Experimental Hypothesis 4: There will be a significant difference between PROP tasters in the type of fat-containing snack they report preferring most

Method

Design

This study employed a between subjects design. Independent variable was genetically determined PROP taster status. Dependent variables were taste responses to pure processed oils and preferred fat-containing snack.

Participants

80 participants were recruited for this study. 49% (n = 39) of these participants had previously taken part in Studies 1 and 2. All participants were female and aged between 16-35 in an attempt to control for age and gender related influences. 79% (n = 63) were self-reported non-smokers whilst 21% (n = 17) were smokers. 11% (n = 9) reported that they were vegetarians. No other specific dietary requirements were reported.

Due to the use of 6-n-propylthiouracil in this study, participants provided informed, written consent for participation and were excluded from taking part if they were pregnant, lactating, had chronic medical conditions (i.e. diabetes, kidney diseases) or food allergies.

Materials

Stimuli

Fat stimuli for this study consisted of samples of corn oil (J. Sainsbury plc, London, UK) and walnut oil (J. Sainsbury plc, London, UK). The fats were stored in a cool, dark environment, in order to minimse interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

PROP taster status was determined using PROP papers, which were made using pieces of $4cm^2$ filter paper and PROP solution consisting of 5 grams of 6-*n*-propylthiouracil and 500ml of water. The filter paper was dipped fully into the PROP solution until completely soaked and then allowed to dry on sheets of aluminium foil. During this process the PROP crystallised into the filter paper. This method is simpler and quicker to apply than the alternative and more complex method of establishing PROP superthreshold taste intensity using sodium chloride (NaCl) as a standard which, it was felt, would reduce success of recruiting participants. The PROP papers method has been reliably used as a means of determining PROP taster status in previous published research (i.e. Intranuovo and Powers 1998).

Questionnaires

In order to rate the perceived taste qualities and preferences for each sample of fat, participants completed response sheets containing 100mm line scales on which they indicated their rating of the stimuli's sweetness, saltiness, sourness, bitterness and liking for taste and texture (all anchored "not at all" and "extremely") and perceived flavour strength (anchored "barely detectable" and "strongest imaginable") (see appendix 1).

Participants were provided with a response sheet containing a choice of fat-containing snacks and asked to specify the one they would most prefer to consume (see appendix 3). Participants were offered a choice of the 10 common snack foods which fell into the following food types: sweet (i.e. biscuits, cake), salty, (i.e. crisps, salted nuts), sweet dairy-based (i.e. ice cream, fruit full-fat yoghurt), savoury (i.e. pizza slice, sausage roll) and fried (i.e. chips, fried chicken).

The labelled magnitude scale (LMS) (Green, Shaffer and Gilmore 1993; Green et al 1996) was used to measure perceived intensity ratings of PROP papers. This is a quasi-logarithmic scale with semantic descriptors along the length of it (Tepper and Ullrich 2002). The scale (see appendix 3) is 100mm long and anchored at the bottom with the phrase "very weak" and at the top with the phrase "strongest imaginable." The phrase "strongest imaginable" is a descriptor of the strongest oral sensation an individual can recall being exposed to. Therefore the scale allows the individual to rate PROP stimulus based upon the full range of their everyday experiences, as opposed to truncating their responses to a standard rating, i.e. very strong (Tepper and Ullrich 2002). The intensity with which supertasters perceive PROP can also exceed the limits of a standard rating scale, thus the LMS also avoids the difficulty of ceiling effects (Prutkin et al 2000). The 15mm point was used as a cut-off for non-tasters and the 71mm point as a cut-off for medium tasters, with any rating above this being labelled supertaster. This method was based upon informal recommendations by Bartoshuk (1998, Gen-X Psychology list-serv)

Procedure

The study took place over two separate sessions. Participants were required not to eat, smoke, clean their teeth or consume anything but water for two hours prior to each session. During the first session participants were presented with a PROP paper and asked to place the whole piece onto their tongue and allow it to become moistened with saliva. When they considered that the taste had reached its maximum intensity they were required to rate its bitterness using the LMS.

During the second session participants were presented with the response sheet to make their selection of their most preferred fat-containing snack. The 2 samples of oil were then presented separately and in random order in small opaque plastic cups, each containing 10ml of the fat stimuli. Participants were unaware as to the identity of each sample. A standard "sip-and-spit" procedure was employed, in which, after tasting, participants were required to expectorate and complete the relevant sensory rating scales. They were then required to rinse three times with distilled water, spitting out each time, before repeating this procedure with the next sample. Participants were required to take a 5 minute break between tasting and evaluating each fat sample. This was a recommended time needed to prevent the flavours of the sample being tasted being suppressed by those of the previous sample (Nguyen and Pokorny 1998).

Analysis

Mixed-design two-way ANOVAs were carried out to test for differences between PROP tasters in their perception of the taste qualities of each oil sample, with oil type and PROP taster status acting as independent variables. Multidimensional scaling (MDPREF) analysis was carried out to look for individual differences in taste responses to the oil stimuli in the context of PROP taster status. Visual inspection of the MDPREF map was applied and the solution was also divided into quadrants providing different subgroups of participants relating to their taste responses to the oils (Greenhoff and MacFie 1994). Having segmented the participants according to their similarity in preference and taste responses, Chi-square analysis was carried out to investigate the relationship between PROP taster status and the specific subgroups.

Chi-square analysis was carried out to examine potential differences between PROP tasters in the preferred type of fat-containing snack they had selected. One-way ANOVAs were carried out to examine the relationship between individual's preferred fat-containing snack type (i.e. sweet, sweet-dairy based, savoury, salty or fried) and the taste qualities and preferences they had perceived in pure processed oils.

Results

PROP taster status

PROP taster classification using the LMS revealed that there were 25 non-tasters (31.25%), 30 medium tasters (37.5%) and 25 supertasters (31.25%).

Taste responses to oil stimuli

Mean taste responses of each PROP taster group for corn oil and walnut oil can be seen in *Table 8*:

Table 8: Mean taste responses to oil for PROP taster groups

			Sweet	Salty	Sour	Bitter	Intensity	Taste Preference	Texture Preference
Corn	NT*	Mean	17.84	9.72	12.72	11.60	18.20	24.92	32.20
Oil		±	24.29	12.11	20.22	17.17	17.79	17.98	25.47
	MT*	Mean	18.43	17.33	16.23	17.60	23.27	17.87	19.40
		±	21.46	21.25	21.59	22.45	15.47	18.18	19.69
	ST*	Mean	19.49	23.00	22.08	21.92	49.04	6.96	15.60
		±	23.57	19.79	25.36	24.18	27.18	9.31	14.28
Walnut	NT	Mean	16.12	29.00	28.32	23.52	48.80	23.32	24.08
Oil		±	19.81	27.89	30.57	26.84	24.33	21.40	23.90
	MT	Mean	22.10	21.33	20.93	24.70	46.43	14.93	20.63
		±	21.97	23.36	26.01	25.76	16.61	15.73	18.39
	ST	Mean	24.96	35.36	28.52	33.72	64.80	15.08	17.80
		±	21.57	24.50	29.49	30.50	21.66	21.39	18.29

* NT – Non taster, MT – Medium taster, ST - Supertaster

Mixed design two-way ANOVAs were carried out and revealed no significant differences between PROP taster groups for perception of any of the four primary taste qualities or taste preferences for walnut oil or corn oil. However significant differences were revealed between PROP taster categories for perceived strength ($F(2, 77) = 3.878$, $p<0.05$) and preference for the texture ($F(2, 77) = 3.582$, $p<0.05$) of the pure processed oils. Bonferroni's post-hoc analyses indicated that the significant main effects for textural preference were due to differences between supertasters and non- and medium tasters, with supertasters reporting lower hedonic ratings for both oils than either medium- or non-tasters. Bonferroni's pairwise comparisons also revealed that, for corn oil, the significant main effect of PROP taster status upon perceived intensity could be attributed to differences between non-tasters and medium- and supertasters, with the latter two groups perceiving the oil as tasting significantly more intense than non-tasters. This was, however, not the case for walnut oil and, as shown in *Table 8*, no significant variation existed between ratings of intensity for non-tasters and medium tasters.

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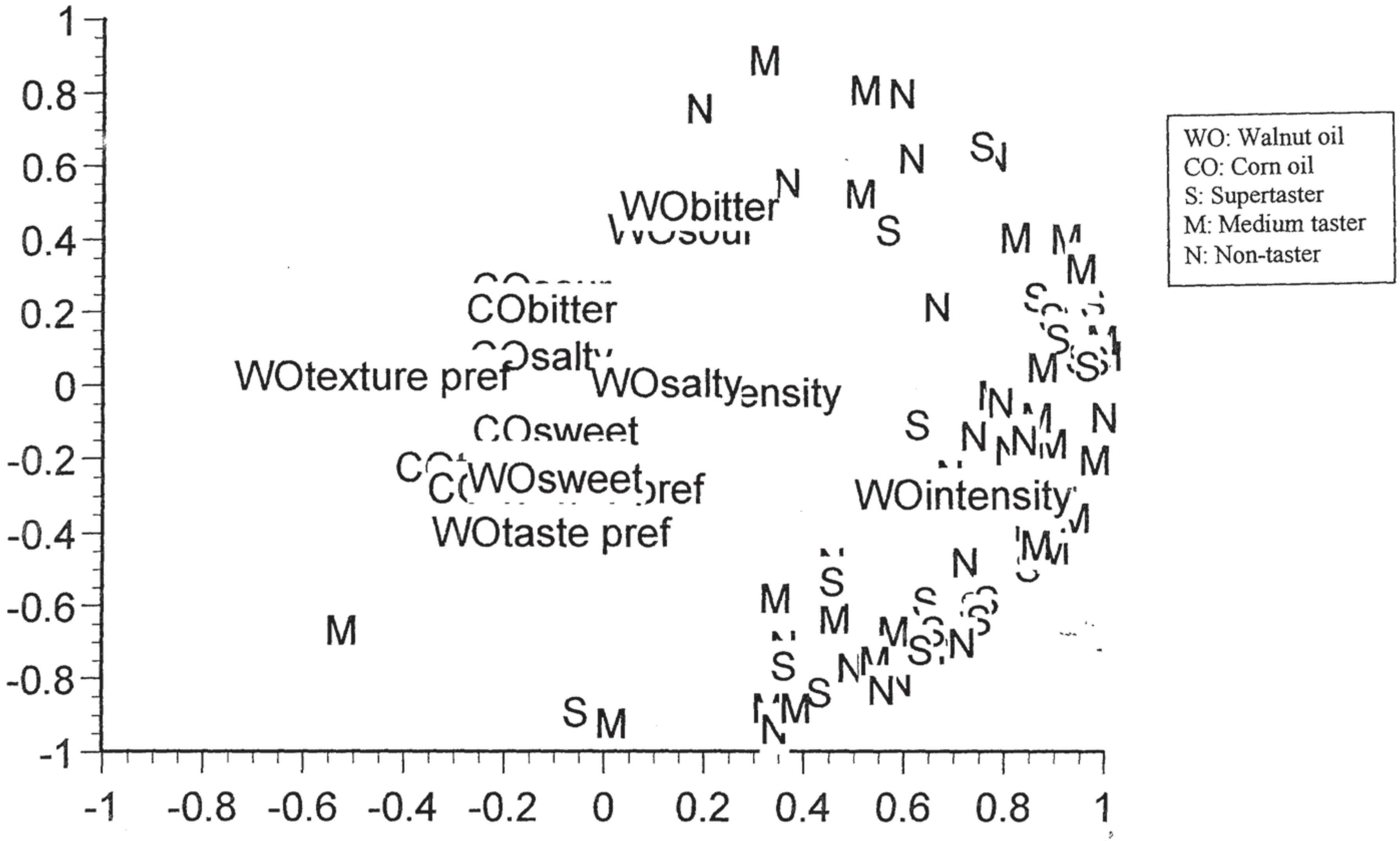
MDPREF analysis

The two-dimensional MDPREF solution is shown in *Figure 3* overleaf. 46.4% of variance is accounted for by a two-dimensional solution. 30.9% of variance accounted for by the first dimension and 15.5% accounted for by the second.

Figure 3: **MDPREF solution illustrating taste responses to pure processed oils relating to PROP sensitivity**



The majority of participants vectors end at the right side of the MDPREF plot, whilst the perceived taste qualities of corn oil and walnut oil are clustered relatively closely together. The plot indicates that walnut oil was perceived as tasting slightly more intense than corn oil by the majority of respondents but that no other consensus of taste qualities were reached. The two oil samples appear to have been judged as fairly similar in their sweetness, saltiness and preferences for taste. Equally, where assessors had rated sourness and bitterness of a given sample, these two taste qualities are plotted as being perceptually similar.

Whilst examination of the MDPREF solution indicates that the respondent sample is not a homogenous grouping its taste responses to corn oil and walnut oil, no definite clear divisions can be observed in terms of PROP taster status. A slightly greater number of supertasters can be observed within the mid-lower right quadrant, indicating an elevated perception of intensity in walnut oil. However these are nevertheless interspersed with medium- and non-tasters. Equally, no clear division can be made in perceptual space between clusters of respondents overall. However, looking at *Figure 3*, respondents in the top right quadrant (referred to as Subgroup 1) appear to be characterised by slightly more bitter and sour taste responses and decreased detection of sweetness and lower preferences for the oils. The bottom right quadrant (referred to as Subgroup 2) hold the opposite view of the oil stimuli and are also characterised by increased perceived intensity of walnut oil. However it should be noted that, overall perceptual differences are small.

Having divided the plot into quadrants (with the centre point being 0.0:0.0) according to similarity of preferences and sensory responses, Chi-square analysis was carried out to see if it was possible to identify either subgroup with sensitivity to PROP. It was found that 49% of respondents fell into Subgroup 1, whilst 51% fell into Subgroup 2. There were 3 outliers from the main subgroups and these were removed from analysis.

The number of non-tasters, medium tasters and supertasters who fell into each subgroup can be seen in *Table 9*:

Table 9: PROP taster status of respondents within taste response subgroups

	Subgroup 1	Subgroup 2	Total
Non-tasters	14	10	24
% of non-tasters	58.3%	41.7%	100%
% of total	18.2%	13%	31.1%
Medium tasters	13	15	28
% of medium tasters	46.4%	53.6%	100%
% of total	16.9%	19.5%	36.4%
Supertasters	12	13	25
% of supertasters	48%	52%	100%
% of total	15.6%	16.9%	32.5%

As can be seen in *Table 9*, there is very little difference between the proportions of supertasters, medium- and non-tasters falling into each subgroup. Chi-square analysis was applied to examine whether any statistical association could be found. Analysis revealed that the assumptions for Chi-square test were met, $\chi^2(2) = 0.837$, $p = 0.66$, indicating a non-significant relationship between PROP taster status and taste response subgroup.

Preferred type of fat-containing snack

23 (28.8%) participants selected a sweet snack food, 20 (25%) chose a salty snack, 17 (21.3%) a savoury snack and 11 (13.8%) selected fried food whilst 9 (11.3%) preferred sweet dairy-based. The preferred fat-containing snack types for each PROP taster category can be seen in *Table 10*:

Table 10: Frequencies for preferred fat-containing snack types relating to PROP taster status

		Preferred fat-containing snack type				
		Fried	Sweet	Sweet dairy-based	Salty	Savoury
Non-tasters	Frequency	4	5	4	7	5
	% of taster group	16%	20%	16%	38%	20%
	% of food group	34.6%	21.7%	44.4%	35%	29.4%
Medium tasters	Frequency	4	11	1	6	8
	% of taster group	13.3%	36.7%	3.3%	20%	26.7%
	% of food group	36.4%	47.8%	11.1%	30%	47.1%
Supertasters	Frequency	3	7	4	7	4
	% of taster group	12%	28%	16%	28%	16%
	% of food group	27.3%	30.4%	44.4%	35%	23.5%

Chi-square analysis was carried out and revealed that there appeared to be no significant relationship between PROP taster status and the fat-containing snack food type which individual's reported most preferring, $\chi^2(8) = 5.387$, $p = 0.716$. However it should be noted that 40% of cells had expected values of less than 5, thus exceeding the required minimum of 20% and reducing the statistical power of the test. However no expected count fell below 1 and the minimum value was 2.81.

One-way ANOVAs were carried out to examine the relationship between the preferred fat-containing snack type chosen and previous sensory responses to the pure processed oil stimuli. Due to the fact that no statistical relationship was established as a function of PROP taster status for preferred fat-containing snack type, no separation was made between PROP tasters for these analyses. Mean ratings for sensory responses to corn oil and walnut oil for each preferred snack group are shown in *Table 11* overleaf:

Table 11: Mean sensory ratings for oil relating to preferred fat-containing snack

	Food type		Sweet	Salty	Sour	Bitter	Intensity	Taste Preference	Texture Preference
Corn	Sweet	Mean	17.09	17.96	20.17	19.82	32.60	18.52	19.22
Oil		±	25.75	19.54	27.94	23.40	23.36	17.40	18.19
	Sweet-	Mean	39.33	29.11	28.33	27.00	40.00	23.11	28.11
	dairy	±	33.22	30.18	25.09	21.12	24.80	19.02	32.78
	Savoury	Mean	13.24	10.88	12.76	7.47	25.00	18.00	20.94
		±	18.79	16.32	14.45	9.00	22.19	17.87	16.49
	Salty	Mean	19.35	14.75	12.50	18.10	31.65	15.90	23.50
		±	22.11	12.16	19.02	24.47	25.80	19.07	23.24
	Fried	Mean	19.49	17.09	15.55	16.18	19.19	6.81	23.27
		±	23.57	18.59	23.13	24.74	23.40	9.20	21.06
Walnut	Sweet	Mean	28.91	29.78	27.04	35.43	54.43	22.43	20.78
Oil		±	22.94	26.38	31.15	31.35	20.27	21.27	17.14
	Sweet-	Mean	26.78	36.33	47.56	41.00	67.22	27.78	34.56
	dairy	±	25.90	28.73	25.16	25.73	24.29	29.13	30.95
	Savoury	Mean	12.71	12.29	15.41	12.35	47.11	12.94	16.12
		±	16.59	14.73	20.93	14.27	20.68	15.38	14.18
	Salty	Mean	18.20	37.85	28.10	28.10	58.40	15.35	19.95
		±	18.58	29.54	30.56	26.35	19.96	18.78	22.43
	Fried	Mean	18.55	24.63	15.90	19.64	37.00	10.45	18.55
		±	21.38	18.01	23.48	30.67	21.61	7.87	17.30

Means indicate that those participants who selected sweet dairy foods (i.e. ice cream, full-fat yoghurt) tended to have elevated ratings for all taste qualities, intensity and preferences across both oil samples.

One-way ANOVAs revealed no statistically significant differences between the food preferences groups for perceived taste qualities or preferences for corn oil. However, significant differences between food preference groups were found for perceived saltiness ($F(4,75) = 2.885$, $p<0.05$), bitterness ($F(4,75) = 2.724$, $p<0.05$) and intensity of walnut oil ($F(4,75) = 3.343$, $p<0.05$).

Levene's test indicated that the assumption of homogeneity of variance had been violated for saltiness (Levene's statistic$(4,75) = 4.679$, $p<0.005$) and bitterness (Levene's statistic$(4,75) = 5.002$, $p<0.005$), therefore the Games-Howell post hoc analysis was applied. The test revealed that, for perceived saltiness, the significant main effect could be attributed to differences between individuals preferring savoury fat-containing snacks and those preferring salty. Means, reported in *Table 10*, indicated that those who chose salty snacks as their preferred type also demonstrated elevated perception of saltiness in walnut oil. In terms of the significant main effect for bitterness, the Games-Howell pairwise analysis indicated that the significant difference lay between those who preferred sweet fat-containing foods and those who selected savoury. Means indicate that individuals selecting sweet foods detected increased bitterness in walnut oil. Levene's statistic revealed that equality of variance could be assumed for perceived intensity of walnut oil, therefore Bonferroni's pairwise comparison was applied and revealed that the significant main effect could be attributed to differences between those who chose sweet dairy fat-containing snacks and those who selected fried foods. Means in *Table 11* indicate that those who reported preferring to consume sweet dairy snacks perceived walnut oil to be more intense than those choosing fried foods. These finding were all also replicated for corn oil but were non-significant ($p>0.05$).

Discussion

The findings of this study indicated that, for corn oil, a linear relationship exists between sensitivity to PROP and detection of the four primary taste qualities and overall intensity of the taste of the oil. By contrast, non-tasters actually perceived walnut oil as being slightly saltier and sourer than medium tasters. However these findings were non-significant due to the small size of the difference and allowances should be made for variation in the use of the line scales, which is a major aspect of this means of data collection. Non-tasters also perceived walnut oil as being slightly more intense than medium tasters and, although a significant main effect was found here, this was attributed to differences between supertasters and medium- and non-tasters.

Despite the apparent linear relationship between PROP sensitivity and perception of the primary taste qualities in corn oil, these findings were not statistically significant. Therefore, Experimental Hypothesis 1, which stated that, "*there will be a significant difference between PROP tasters in their perception of primary taste qualities in pure processed oil stimuli*" is rejected. However, Experimental Hypothesis 2, which stated "*there will be a significant difference between PROP tasters in their perceived intensity of pure processed oil stimuli,*" can be upheld. Overall, the above findings suggested that PROP tasters and non-tasters did not appear to perceive pure processed oils as having differing taste qualities but did vary in the intensity at which they detected these characteristics, with supertasters rating them most strongly. This provides further evidence of a taste component to sensory responses to fat and suggests that, should techniques such as Free Choice Profiling be applied, allowing individuals to generate their own taste descriptors, a similar pattern of results could still be expected. It also provides further support for Gilbertson et al's (1997) hypothesis that fat appears to stimulate all the major taste receptors. These results are also consistent with the finding of this study relating to overall perceived intensity and builds upon the results of previous published research which had indicated that tasters detected fat more intensely in salad dressings (Tepper and Nurse 1997) and liquid dairy stimuli (Drewnowski, Henderson and Barrett-Fornell 1998).

The fact that corn oil demonstrated more consistent results than walnut oil could be partially linked to findings in Study 4 which indicated that corn oil appeared to be characterised by a "fatty" flavour, whilst walnut oil was characterised by more "smoky, bitter, burnt" taste qualities. However since PROP taster status itself is determined by sensitivity to bitterness the findings regarding non-tasters and medium tasters responses to walnut oil are still unexpected. Somewhat surprisingly, the above findings also indicated that, the greatest sensory gap in perceived intensity of pure processed oil was not between tasters and non tasters, but between supertasters and medium- and non-tasters, whilst no significant differences existed between medium and non-tasters.

In terms of hedonic ratings, the results of this study indicated an inverse relationship between PROP sensitivity and taste and texture preferences for both corn and walnut oil. These findings were only significant for textural preference, thus partially upholding Experimental Hypothesis 3, which stated, "*there will be a significant difference between PROP tasters in their preferences for the pure processed oil stimuli.*" These results may be related to the fact that the elevated intensity perceived by tasters was considered unpleasant. Previously cited research has hypothesised that PROP tasters consider stimuli with high fat contents too intense to be palatable (Tepper and Ullrich 2002) but this has been based upon assumptions that fat is being detected texturally. The absence of significant findings relating to taste preference for pure processed oils fails to add a taste component to this hypothesis.

In addition to the aggregated analyses, multidimensional scaling was also employed to examine the link between PROP taster status and taste responses to the pure processed oils. As in Study 2, the MDPREF solution plot generated by this study indicated that the respondent sample were not homogenous in their perception of taste characteristics and preferences for corn oil and walnut oil. However, the plot provided little evidence that this individual variation could be linked to sensitivity to PROP. Visual inspection indicated a cluster of supertasters and medium tasters perceptually close to perceived intensity of walnut oil supporting previous evidence for increased sensitivity to fat with sensitivity to PROP (Tepper and Nurse 1997). However a number of non-taster respondents were also mapped onto this area, reducing the impact of this observation.

By dividing respondents into two subgroups, it appears that Subgroup 1 could be basically characterised by greater perception of bitterness and sourness, whilst Subgroup 2 was associated with increased detection of sweetness and elevated preferences. Thus, it may have been expected, on the basis of previous research describing PROP taster's elevated sensitivity to bitterness and decreased hedonics for fat-containing stimuli (Duffy et al 1996; Tepper and Nurse 1997; Forrai and Bankovi 1984; Duffy Weingarten and Bartoshuk 1995), that more medium- and supertasters would have been located in Subgroup 1. However, both visual inspection and Chi-square analysis indicated that this was not the case and that PROP tasters and non-tasters appeared to be scattered relatively evenly throughout both subgroups.

The failure to find any discernable pattern on the MDPREF plot between PROP taster status and taste responses to fats could be attributed to a number of factors. It is possible that had a greater number of participants been recruited for this study, more definite clusters of respondents may have emerged. However, given the degree of integration between super-, medium- and non-tasters and that the number of participants in this study is fairly substantial, this would seem unlikely to have had a major effect upon the solution. The exploration of possible variation between the taste qualities perceived in pure fats was relatively exploratory, having not been investigated by previous published research. However differences in preferences and intensity in relation to PROP sensitivity were more likely to have been expected due to the fact that they had been described in previous studies (Duffy et al 1996; Tepper and Nurse 1997). Yet, it must be taken into account that these studies had used stimuli such as salad dressings (Tepper and Nurse 1997) and milk products (Duffy et al 1996) as opposed to pure processed oils. The taste qualities of pure fats may be viewed as relatively less pleasant to all respondents, regardless of PROP taster status, thus minimising the differences revealed and leading to the intergration of participants observed on the MDPREF solution map.

A further aim of this study was to investigate whether PROP sensitivity-related differences could be found in the type of fat-containing snack foods an individual reported most preferring. The results indicated that there was no statistical relationship between preferred fat-containing food type and PROP taster status, thus leading to the rejection of Experimental Hypothesis 4, which stated, "*there will be a significant difference between PROP tasters in the type of fat-containing snack they report preferring most.*" These findings imply that PROP taster status does not appear to effect the specific type of fat-containing foods an individual selects. This may be related to the fact that PROP tasters do not appear to detect different taste qualities in pure fats, just the same characteristics more intensely. However it should be taken into account that the method used to judge preference for fat-containing food types was very simple and arbitrary and may not have contained a wide enough range of fat-containing foods to detect significant differences. Attempting to locate differences using basic categories may be too simplistic and it is possible that PROP tasters and non-tasters may only exhibit varying responses to specific food types. Equally the number of participants used for this study may have been too small to detect individual differences in this area.

Despite the fact that it could not be related to PROP taster status, examination of the relationship between the most preferred fat-containing snack type and sensory responses to pure fats produced some interesting findings. Those who selected sweet dairy snacks (ice cream, full fat yoghurt) as their preferred choice gave significantly elevated, though not significantly so, ratings for pure fat across all taste qualities, intensity and preference. Fat is a very obvious component of these food types and therefore those who choose to consume them may be more likely to be individuals who prefer its tastes and textures, whilst regular consumption may also have increased their sensitivity to it. Results also indicated that those who chose to consume salty fat-containing snacks gave significantly greater ratings for the saltiness of walnut oil, suggesting that their sensitivity to salt may be related to their selection of this food type, either by increasing their liking for it or by increasing their association of fat with saltiness through regular consumption.

An elevated rating of bitterness in walnut oil was found by those listing sweet fat-containing snacks as their favourite, when compared with those who preferred savoury foods. This may be due to the fact that such individuals are more used to consuming dietary fat with added sugar content and therefore without this perceived the fat as tasting more bitter than those who consume dietary fat in savoury form anyway. However this hypothesis is tentative due to a lack of previous research within this area. Finally, intensity ratings of walnut oil were found to be significantly greater in those who selected sweet dairy foods when compared with those who chose fried snacks. One possible explanation for this is the fact that, whilst fat is an obvious aspect of sweet dairy foods, it is disguised by sugar and does not take the form of pure oil. Therefore this is likely to have been perceived as more intense individuals preferring sweet dairy foods than those who choose to consume more fried snacks, where oil is an obvious component of taste and texture. Despite the speculative nature of some of these hypotheses, these findings clearly indicate that, regardless of PROP taster status, the relationship between taste responses to pure fats and fat-containing food preferences and selection requires further investigation.

Conclusion

The overall findings of this study in relation to PROP sensitivity and taste responses to pure processed oils indicated that, no specific taste qualities could be associated with tasters and non-tasters suggesting that similar types of taste qualities are detected in fat across all individuals. However aggregated analysis indicated that the intensity with which these taste qualities were perceived did appear to differ, with increasing intensity of each taste characteristic being present with increased sensitivity to PROP. This appeared to have a negative effect upon preferences for pure processed oils and non-tasters who perceived the fat as being less intense in tastes and flavours tended to prefer its taste and texture more. The failure to find a clear relationship between genetic sensitivity to PROP and taste responses to pure fats suggests that other additional hidden factors also exert an influence when sensory judgements are made. The relatively unpleasant taste characteristics elicited when tasting and consuming pure processed oils may also have served to disguise any PROP related differences. Equally, no relationship was found between PROP sensitivity and the type of fat-containing food an individual reported preferring to consume. However this warrants more detailed investigation in further study.

Study 5

The relationship between genetic PROP taster status and preference for fat containing foods

Introduction

The findings of the previous study (Study 4) indicated that, whilst PROP taster status appeared to be related to taste responses to pure processed oils, no significant relationship could found between PROP sensitivity and the type of fat-containing food an individual reported preferring to consume. However, as was stated within this study, the methodology used was very simplistic, only providing respondents with a choice of 10 fat-containing snack foods, which were divided into 5 food categories. Therefore it was concluded that attempting to locate differences using basic categories may be too simplistic and it is possible that PROP tasters and non-tasters may only exhibit varying responses to specific food types.

Previous published research has addressed the relationship between food preferences and PROP sensitivity and, in relation to fat-containing foods, a number of significant differences in hedonic rating have been found. Reduced acceptance by PROP/PTC sensitive individuals has been reported for whipped cream (Forrai and Bankovi 1984), ice cream, donuts, whole milk, mayonnaise, bacon and sausage (Duffy and Bartoshuk 2000). However, within previous published research, fat-containing food tends to be represented by only a few food types and no previous published research has carried out a comprehensive study adequately covering the wide range of dietary fat sources available for consumption. It is clear that fat can be consumed in foods with a wide variety of properties and tastes. In order to gain a more complete understanding of the relationship between PROP sensitivity and preferences for dietary fat it is necessary to explore taste responses to as many food sources of fat as possible. Therefore, the aim of this study was to investigate further the relationship between PROP sensitivity and preferences for fat-containing foods.

A food preference questionnaire was deemed to be the most appropriate means of determining food preferences. This method is retrospective and thus may be considered less accurate than actually requiring the participants to taste the specific foods prior to rating. However in order to gain the most complete representation of dietary fat sources possible, the questionnaire contained 53 fat-containing foods and it would've clearly been impractical to have requested that respondents actually taste each of these before recording their preference. Equally, the carry-over effects with the use of such a large number of food samples would have been likely to eliminate the advantage of greater accuracy anyway.

As has been discussed in the previous study, elevated sensitivity to PROP has been associated with decreased preference for a number of fat-containing foods and, on the basis of the previous study also appears to be related to reduced hedonic ratings for pure processed fats. However it is clear that PROP tasters must consume some sources of dietary fat. Therefore, in examining a relatively comprehensive range of the most commonly consumed fat-containing foods, it may be possible to identify particular food types which are regarded as being less palatable by PROP tasters. It is possible that these foods may be ones where fat is a more obvious component of the food matrix. Equally however, other taste qualities also present within the food may exert an influence. PROP tasters have been found to be more sensitive to oral stimuli such as capsaicin (Bartoshuk et al 1994; Tepper and Nurse 1997) and to prefer mild, as opposed to sharper tasting foods (Forrai and Bankovi 1984). Thus, fat-containing foods which also have such taste properties may produce more PROP-related hedonic differences. For the purpose of aggregated analysis, the following hypothesis was generated:

Hypothesis 1: Individuals with increased sensitivity to PROP will demonstrate significantly reduced preferences for fat-containing foods

Method

Design

This study employed a between subjects design with the independent variable being PROP taster status and the dependent variables being hedonic responses for 53 fat-containing foods.

Participants

80 participants were recruited for this study. This was the same participant group who had been recruited to take part in the previous study. 49% (n = 39) of these participants had also previously taken part in Studies 1 and 2. All participants were female and aged between 16-35 in an attempt to control for age and gender related influences. 79% (n = 63) were self-reported non-smokers whilst 21% (n = 17) were smokers. 11% (n = 9) reported that they were vegetarians. No other specific dietary requirements were reported.

Due to the use of 6-n-propylthiouracil in this study, participants provided informed, written consent for participation and were excluded from taking part if they were pregnant, lactating, had chronic medical conditions (i.e. diabetes, kidney diseases) or food allergies.

Materials

Stimuli

PROP taster status was determined using PROP papers, which were made using pieces of 4cm² filter paper and PROP solution consisting of 5 grams of 6-*n*-

propylthiouracil and 500ml of water. The filter paper was dipped fully into the PROP solution until completely soaked and then allowed to dry on sheets of aluminium foil. During this process the PROP crystallised into the filter paper. This method is simpler and quicker to apply than the alternative and more complex method of establishing PROP superthreshold taste intensity using sodium chloride (NaCl) as a standard which, it was felt, would reduce success of recruiting participants. The PROP papers method has been reliably used as a means of determining PROP taster status in previous published research (i.e. Intranuovo and Powers 1998) and was successfully applied in Study 4.

Questionnaires

In order to determine preference for fat-containing foods, participants were provided with food preference questionnaires containing a list of 53 fat-containing foods (see appendix 6). Hedonic response for each food was rated using 100mm line scales, anchored "not at all" (0mm) and "extremely" (100mm).

The labelled magnitude scale (LMS) (Green, Shaffer and Gilmore 1993; Green et al 1996) was used to measure perceived intensity ratings of PROP papers. This is a quasi-logarithmic scale with semantic descriptors along the length of it (Tepper and Ullrich 2002). The scale is 100mm long and anchored at the bottom with the phrase "very weak" and at the top with the phrase "strongest imaginable." The phrase "strongest imaginable" is a descriptor of the strongest oral sensation an individual can recall being exposed to. Therefore the scale allows the individual to rate PROP stimulus based upon the full range of their everyday experiences, as opposed to truncating their responses to a standard rating, i.e. very strong (Tepper and Ullrich

2002). The intensity with which supertasters perceive PROP can also exceed the limits of a standard rating scale, thus the LMS also avoids the difficulty of ceiling effects (Prutkin et al 2000). The 15mm point was used as a cut-off for non-tasters and the 71mm point as a cut-off for medium tasters, with any rating above this being labelled supertaster. This method was based upon informal recommendations by Bartoshuk (1998, Gen-X Psychology list-serv)

Procedure

Participants were required not to eat, smoke, clean their teeth or consume anything but water for two hours prior to taking part in this study. During the first part of the study participants were presented with the food preference questionnaires, which they were required to complete. Following completion of these, participants were presented with a PROP paper and asked to place the whole piece onto their tongue and allow it to become moistened with saliva. When they considered that the taste had reached its maximum intensity they were required to rate its bitterness using the LMS.

Analysis

One-way ANOVAs were carried out to explore the relationship between sensitivity to PROP and preference for each fat-containing food. Principal components analysis was used in an attempt to reduce individual foods into meaningful food categories.

Results

PROP taster status and preference for individual fat-containing foods

Mean preferences for each fat-containing food relating to PROP taster status can be seen in *Table 12*:

Table 12: Mean hedonic ratings for fat-containing foods relating to PROP taster status

		PROP taster status		
Food		Non-taster	Medium taster	Supertaster
Avocado	Mean	38.44	36.68	44.47
	±	35.78	31.55	31.22
Bacon	Mean	72.78	62.61	56.00
	±	28.42	28.96	33.69
Beef	Mean	67.52	63.83	60.12
	±	28.01	29.17	35.02
Burgers	Mean	57.09	45.17	51.00
	±	21.94	27.28	28.67
Biscuits	Mean	64.00	76.57	75.44
	±	27.59	22.94	23.26
Brie	Mean	50.78	53.31	56.05
	±	32.06	34.61	33.78
Butter	Mean	55.88	57.77	48.52
	±	28.06	27.97	28.80

Food		PROP taster status		
		Non-taster	Medium taster	Supertaster
Cakes	Mean	75.28	71.37	75.80
	±	18.04	21.74	21.05
Cheddar	Mean	74.12	70.47	75.32
cheese	±	19.88	28.89	28.01
Chicken	Mean	73.48	78.97	79.60
	±	21.42	22.96	27.26
Chips	Mean	66.64	73.33	72.80
	±	18.99	18.58	26.51
Coconut	Mean	48.20	47.55	47.96
	±	26.91	29.50	37.24
Cream	Mean	54.40	52.37	59.28
	±	27.00	31.38	31.58
Cream cheese	Mean	49.71	48.03	48.20
	±	27.55	33.86	34.14
Cream	Mean	54.43	50.47	52.83
crackers	±	21.49	25.23	26.25
Crème fraiche	Mean	35.60	45.82	41.53
	±	28.53	29.92	30.21
Crisps	Mean	65.42	73.73	67.72
	±	17.58	25.48	26.38
Croissants	Mean	62.08	64.14	70.84
	±	29.85	21.59	25.73

Food		PROP taster status		
		Non-taster	Medium taster	Supertaster
Curries	Mean	61.48	68.00	67.56
	±	31.72	33.17	32.88
Custard	Mean	55.52	61.33	56.00
	±	27.28	29.14	30.82
Dark chocolate	Mean	49.68	41.53	46.64
	±	32.85	34.98	39.16
Donuts	Mean	61.40	59.87	59.00
	±	22.82	26.15	31.40
Duck	Mean	57.56	46.58	36.85
	±	29.08	31.15	33.50
Eggs	Mean	65.04	59.73	69.60
	±	16.71	23.08	23.10
Fish n chips	Mean	64.26	72.21	59.40
	±	20.35	22.80	33.50
Fried rice	Mean	54.56	64.86	61.96
	±	27.82	28.54	31.60
Fried breakfast	Mean	64.96	56.03	55.40
	±	31.70	28.65	32.27
Fromage frais	Mean	41.86	48.58	44.57
	±	32.86	30.85	30.29
Ice cream	Mean	69.56	69.93	78.60
	±	22.27	26.17	19.58

Food		PROP taster status		
		Non-taster	Medium taster	Supertaster
Lamb	Mean	65.04	68.59	55.28
	±	22.84	28.22	37.24
Margarine	Mean	54.48	41.33	56.33
	±	19.30	25.36	22.82
Marscarpone	Mean	36.67	40.63	32.56
cheese	±	28.38	30.23	32.89
Mayonnaise	Mean	51.28	55.17	55.24
	±	30.40	29.55	34.92
Milk chocolate	Mean	77.36	82.13	85.04
	±	22.55	20.32	15.35
Peanuts	Mean	58.42	56.70	55.00
	±	26.77	29.82	32.64
Peanut butter	Mean	43.00	33.30	22.96
	±	30.42	31.81	24.01
Pesto	Mean	45.07	52.17	42.73
	±	27.52	29.98	38.73
Pizza	Mean	74.08	74.47	74.08
	±	22.12	23.41	27.90
Popcorn	Mean	56.80	58.57	53.88
	±	27.13	26.71	28.67
Pork	Mean	60.35	58.71	53.16
	±	28.47	28.27	34.65

Food		PROP taster status		
		Non-taster	Medium taster	Supertaster
Roast dinner	Mean	80.00	71.28	77.72
	±	20.29	28.59	28.26
Salad dressing	Mean	47.08	58.33	54.24
	±	27.90	33.25	31.06
Sausages	Mean	64.17	57.39	57.96
	±	26.18	29.59	32.54
Savoury pies	Mean	53.25	48.31	43.64
	±	27.87	24.78	30.04
Semi skimmed	Mean	64.32	58.07	62.88
milk	±	25.01	30.69	23.32
Skimmed milk	Mean	37.04	40.34	48.96
	±	26.37	35.93	34.67
Sour cream	Mean	29.55	28.70	30.53
	±	27.89	31.72	31.81
Stilton	Mean	38.52	34.48	32.25
	±	37.06	36.52	35.31
Sweet pies	Mean	68.04	61.93	60.79
	±	23.80	27.89	27.29
Taramasalata	Mean	36.63	39.74	42.86
	±	29.23	32.01	34.62
White	Mean	43.44	54.90	68.08
chocolate	±	30.34	33.74	25.78

Food		PROP taster status		
		Non-taster	Medium taster	Supertaster
Whole milk	Mean	44.76	40.68	49.08
	±	30.51	34.21	32.93
Yoghurt	Mean	66.64	72.72	65.36
	±	26.15	22.29	30.69

One-way ANOVAs were carried out. With Bonferroni's correction for multiple comparisons, a significant difference was revealed between PROP tasters in preference ratings for white chocolate ($F(2,77) = 4.120$, $p<0.05$). Levene's test indicated the assumption of homogeneity of variance had been met and Bonferroni's pairwise comparison was carried out. This post-hoc test revealed that the significant main effect was related to differences between non-tasters and supertasters, with mean values indicating that supertasters responded with greater hedonic ratings.

Reduction of individual foods

Principal components analysis was used in an attempt to reduce the individual fat-containing foods into meaningful food groups on the basis of their hedonic ratings. Pearson's bivariate correlation was used to screen the data prior to reduction and revealed that skimmed milk failed to correlate significantly with any of the other foods and was therefore eliminated from the analysis. However, no meaningful solution could be reached.

The fat-containing foods were also reduced into 5 food categories manually and mean hedonic ratings for each food type was calculated. The following categories were devised; Meat (bacon, beef, burgers, chicken, duck, lamb, pork, roast dinner, sausage), Dairy (brie, butter, cheddar cheese, cream, cream cheese, crème fraiche, ice cream, margarine, semi-skimmed milk, sour cream, whole milk, yoghurt), Sweet (biscuits, cake, donuts, ice cream, milk chocolate, white chocolate), Fried (chips, crisps, fish n chips, fried rice, fried breakfast) and Cheese-based (brie, cheddar cheese, cream cheese, pizza, stilton). Mean hedonic ratings for each food type relating to PROP taster status can be seen in *Table 13*:

Table 13: Mean hedonic ratings for fat-containing food groups relating to PROP taster status

		PROP taster status		
Food type		Non-taster	Medium taster	Supertaster
Meat	Mean	66.28	60.49	58.80
	±	18.05	21.05	22.91
Dairy	Mean	54.41	53.11	58.70
	±	14.09	13.94	10.60
Sweet	Mean	65.17	69.13	73.66
	±	14.21	16.44	14.80
Fried	Mean	63.74	67.06	63.05
	±	17.10	15.43	18.64
Cheese-based	Mean	59.50	59.73	63.09
	±	19.06	20.48	16.87

One-way ANOVAs were carried out and no significant differences were found between PROP tasters in their preference ratings for any of the fat-containing food groups ($p>0.05$).

Discussion

The findings of this study indicated that, of the 53 fat-containing foods surveyed, a significant difference relating to PROP sensitivity was only found for white chocolate. Post-hoc analyses revealed that supertasters gave significantly greater hedonic ratings for the confectionary than non-tasters. Equally, this finding was the opposite to the expected effect that increased PROP sensitivity would lead to reduced preferences for fat-containing foods.

Similar foods listed on the preference questionnaire were placed into categories (meat dairy, sweet, fried and cheese-based). However subsequent analysis also failed to find any significant differences between PROP taster groups in their hedonic responses to these food groups. Equally, whilst mean preferences declined with increasing PROP sensitivity for hedonic responses to meat, this expected effect was not seen within any of the other food categories.

Overall, on the basis of these findings, hypothesis 1, which stated that, *"individuals with increased sensitivity to PROP will demonstrate significantly reduced preferences for fat-containing foods"* must be rejected. The results of this study also fail to replicate those found in previous published research, which focused upon a much more limited range of fat-containing foods, but reported decreased preferences in PROP-sensitive individuals. These findings also fail to extend the results of Study 4 by indicating that the reduced preference for pure processed oils, previously reported in this study, is not necessarily transferable to actual fat-containing foods. However, this does support the findings related to preference for fat-containing snacks reported in Study 4.

One possible reason for this inconsistency between taste responses to pure fats and that shown to fat-containing foods is that the taste qualities of fat are changed and masked by the other components of the specific food. The increased sensitivity to the taste qualities of pure fat revealed in study 4 by PROP tasters may be a major cause of their overall dislike and if these qualities are disguised by other aspects of the food may no longer apply, thus PROP related differences are reduced.

It must also be taken into account that previous published research has reported PROP sensitive variation in several of the fat containing foods which were listed on the food preference questionnaire in this study, including cream (Forrai and Bankovi 1984), ice cream, donuts, whole milk, mayonnaise, bacon and sausage (Duffy and Bartoshuk 2000). However due to the fact that this entire area of research is relatively new, these findings themselves have yet to be consistently replicated. Equally it must be taken into account that only examining the influence of PROP sensitivity upon preferences for fat-containing foods does not remove the contribution made by additional factors. A recent study by Tepper and Ullrich (2002) indicated that a relationship could be found between PROP sensitivity and Body Mass Index (BMI), possibly through the link to fat consumption. However when dietary restrain was taken into account it was reported that the significant association between PROP sensitivity and BMI was only present in individuals with low levels of dietary restraint, whilst no differences in BMI across PROP taster groups were located in respondents with high dietary restraint (Tepper and Ullrich 2002).

In terms of methodological issues within this study, the use of a retrospective food preference questionnaire, as opposed to actual food samples, could be regarded as a possible contributory factor for these findings. However previous published research has successfully used this method (i.e. Duffy, Weingarten and Bartoshuk 1995), suggesting that it is unlikely to have been the sole cause. Equally, the rating food samples itself could be criticised for removing the context of normal food consumption and thus producing artificial results. The failure of the principal components analysis in producing a meaningful solution is likely to have been related to the relatively small correlations between individual foods. This suggests that, in this study at least, hedonics are not necessarily a good predictor of similar food types. Thus, despite the non-significant results, the manual assignment of foods into categories must be regarded with caution.

Overall, whilst methodological issues may have been a contributory factor to the findings of this study, they nevertheless suggest that PROP taster status is not a reliable predictor of preferences for fat-containing foods. Food preference is a complex issue, highly sensitive to factors such as context, lifestyle, advertising and familial and peer influence. This is particularly the case with fat-containing foods where dieting and health issues and concerns are likely to be involved. Therefore it may be that, whilst PROP sensitivity may exert an influence upon taste responses to pure fats, where actual fat-containing foods are concerned, the additional factors involved in predicting preference may reduce and confuse the influence of PROP sensitivity to such an extent that its relationship is no longer clear.

Chapter 7

The relationship between self-reported intake of fat-containing foods, Body Mass Index, dieting behaviour and taste responses to fats.

Study 6

Introduction

Research suggests that, on average, individuals in Western societies consume 37-42% of their food energy as dietary fat (Mela 1995). However, relatively little is actually known about the relationship between consumption of fat-containing foods and sensory responses to fat in its pure form. Previous published research has produced conflicting results, with some studies reporting no relationship between regular dietary fat consumption and preferences for and ability to perceive fat in stimuli (i.e. Pangborn, Bos and Stern 1985; Mela and Sacchetti 1991), whilst other have reported some evidence for differences related to dietary intake (i.e. Mela 1989, unpublished, Mattes 1993). However methodology used within these studies has been highly variable, making comparison difficult and no attempt has been made to examine the relationship between actual perceived taste qualities in pure fats or oils.

Given the nutritional significance of dietary lipids and their potential role in weight gain, the issues of fat consumption, body weight and dieting behaviour are clearly inter-related. As with dietary consumption, the existing evidence concerning body weight and sensory responses to fats tends to be concerned with differences in preferences and abilities to detect fat in artificial stimuli such as sweetened dairy products (i.e. Drewnowski et al 1985) and no published attempt has been made to examine taste quality responses to pure fats. Findings from some of these studies have been suggestive of an increased preference for fat-containing stimuli and higher fat levels both in obese individuals (Drewnowski et al 1985) and with increasing Body Mass Index (BMI) (Mela and Sacchetti 1991). However, other non-significant findings in the relationship between body weight and sensory responses to fat have also been reported (i.e. Warwick and Schiffman 1990; Pangborn, Bos and Stern 1985). As with dietary fat consumption, studies tended to use variable methodology making direct comparison or replication difficult. Equally, another possible reason for such inconsistencies relates to the argument that obese individuals rarely behave as an homogenous group (Drewnowski 1985) and thus distinctions on the basis of body weight alone are too simplistic and may obscure true individual differences which are still related to body composition.

Support for this hypothesis can be drawn from findings indicating that weight loss behaviour may be related to sensory preferences for fat, with the presence of "yo-yo" dieting or recent weight fluctuations being associated with increased preference in fat-containing stimuli (Drewnowski and Holden-Wiltse 1992; Crystal, Frye and Kanerek 1995; Drewnowski, Kurth and Rahaim 1991). Of further interest are the sensory responses to fat of individuals with eating disorders. Clearly these responses may be a cultural, rather than clinical phenomenon (Simon et al 1993), and very few sensory studies have been carried out with an eating disordered population. However evidence has indicated that, despite the differing food habits relating to their conditions, both emaciated anorectics and bulimics disliked intense concentrations of fat in stimuli, when compared with controls (Drewnowski et al 1987), providing further support for the influence of weight status or dietary behaviours.

As discussed previously, none of these factors have been examined in the context of actual taste responses to pure fats which are used within an everyday diet. The fact that differences have been found in preferences for fat-stimuli, but not in abilities to accurately detect fat levels (i.e. Drewnowski et al 1985), raises the possibility that these variations may be related to differences in the taste qualities detected in fats. Therefore, the purpose of this study was to examine the relationships between taste responses to pure processed oil and regular dietary fat consumption, BMI and dieting behaviour.

The fat stimulus selected for this study was corn oil, since it was found in Study 3 to be the processed oil most representative of a "fatty" flavour, probably due to the fact that its derivative was not as intense in taste as oils such as walnut oil. Dietary fat consumption was investigated using a retrospective food frequency questionnaire containing 53 fat-containing foods of varying types. This was in order to gain information on both overall fat consumption and the specific types of dietary fat an individual chose to consume to establish whether either of these factors was related to taste responses to pure oil, i.e. did individuals who ate more savoury foods, such as chips, perceive fat differently to those who consumed more sweet foods, such as ice cream.

The use of a food frequency questionnaire carries with it the advantage that it measures usual intake, thus not portraying a false picture based on a given time period, and is relatively simple and easy for participants to complete. The tool has also been used extensively and successfully previously published research (Block 1982). It could be argued that the fact that the method does not provide a direct quantitative measure of intake, it may be subject to more respondent inaccuracies or errors of omission than methods such as dietary diaries. Equally however, such methods are time-consuming and participants may still fail to complete them specifically or accurately leading to misleading results and reporting biases (Block 1982; Reed et al 1997). Equally it has been argued that, because food diaries are rarely recorded form more than a brief period (3-7 days), they may fail to represent the participants usual food consumption habits (Reed et al 1997).

Underreporting is a significant obstacle in the collection of accurate habitual dietary intake data (Macdiarmid and Blundell 1998; Trabulsi and Schoeller 2001) and may be the result of either genuine measurement error or deliberate falsification (Klesges, Eck and Ray 1995). Studies have estimated that, on average, the prevalence of underreporting in dietary consumption ranges from 18 – 70% of participants (Klesges, Eck and Ray 1995; Macdiarmid and Blundell 1998; Jonnalagadda, Benardot and Dill 2000; Goris, Meijer and Westerterp 2001). It has been suggested that a range of physical and psychological characteristics play a role in underreporting bias (Trabulsi and Schoeller 2001). Factors which have been associated with this include dietary restraint, smoking, increased Body Mass Index, obesity, social desirability and gender, with females more likely to underreport than males (Macdiarmid and Blundell 1998; Jonnalagadda, Benardot and Dill 2000; Muhlheim 1996; Klesges, Eck and Ray 1995). A number of previous published studies have suggested that food items with a negative healthy image and, specifically dietary fat, are more likely to be underreported than healthier foods (Macdiarmid and Blundell 1998; Goris, Meijer and Westerterp 2001; Vuckovic et al 2000). A study of obese and non-obese females by Poppitt et al (1998) conflicted with this and suggested that, whilst snack foods were more likely to be reported inaccurately, overall estimates of dietary fat intake tended to be realistic. However it should be taken into account that many snack foods, i.e. crisps, chocolate, biscuits, have relatively high fat contents anyway. Overall, on the basis of these findings, it should be taken into account that, given that the food frequency questionnaire applied in this study lists solely fat-containing food items underreporting bias may be an issue when interpreting the findings.

In relation to taste responses to fat and dietary consumption, BMI and dieting behaviour, the aims of this study were to test the following hypotheses:

Experimental Hypothesis 1: There will be a significant relationship between taste responses to corn oil and usual dietary intake of fat-containing foods

Experimental Hypothesis 2: There will be a significant relationship between taste responses to corn oil and Body mass Index

Experimental Hypothesis 3: there will be a significant relationship between taste responses to corn oil and dieting behaviours

Method

Design

This study employed a between subjects design. Independent variables were body mass index, weight control history and normal consumption of fat-containing foods. Dependent variables were perceived taste qualities and preferences for pure processed oil.

Participants

90 participants were recruited for this study. 78 (87%) of these participants had previously taken part in Studies 4 and 5. All participants were females aged between 16 - 35 years old to control for gender and age as influencing factors. Body Mass Indices (BMI) ranged from 16.45 to 39.26. The mean BMI was 24.8, with a standard deviation of 4.84. 12 (13%) participants had a BMI of <20 which could be classified as below normal weight (Garrow 1984). 43 (48%) had a BMI of 20 – 24.9, within the normal weight range (Garrow 1984). 20 (22%) had a BMI ranging 25 – 29.9, classified as grade 1 obesity (Garrow 1984). 15 (17%) had a BMI ranging 30 – 39.9, categorised as grade 2 obesity (Garrow 1984).

77% (n = 69) were self-reported non-smokers whilst 23% (n = 21) were smokers. 11% (n = 10) reported that they were vegetarians. No other specific dietary requirements were

All participants were naïve as to the purpose of the study.

Materials

Stimuli

Sensory stimuli for this study consisted of a 10ml sample of corn oil (J. Sainsbury plc, London, UK). The fat was stored in a cool, dark environment, in order to minimse interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

Questionnaires

In order to rate the perceived taste qualities and preferences for corn oil, participants completed response sheets (see appendix 1) containing 100mm line scales on which they indicated their rating of the stimuli's sweetness, saltiness, sourness, bitterness and liking for taste and texture (all anchored "not at all" and "extremely") and perceived flavour strength (anchored "barely detectable" and "strongest imaginable"). Participants were also required to record the taste quality they perceived to be most dominant in the oil sample, given a choice of sweet, salty, sour and bitter.

Self-reported estimated intake of 53 fat-containing foods was measured using a 9-category food frequency checklist (see appendix 4). The 9 categories used were "Never," "Rarely," "Once a month," "2-3 times a month," "1-2 times a week," "3-4 times a week," "5-6 times a week," "Every day" and "More than once a day." Participants were also asked to record the frequency with which they used corn oil for cooking purposes using the same categories.

Participants were provided with a questionnaire asking them to record whether they were currently dieting, as a basic measure of restraint. They were also asked if they had ever dieted to lose weight. If so they were then required to indicate on a 100mm line scale the point which best described how frequently they dieted (anchored "Never" and "Always"), how successful they were in reaching their target weight and how successful they were in maintaining this weight (both anchored "Extremely successful" and "Not at all successful"). Measurements of participant's weight and height were taken and recorded within the laboratory (see appendix 4).

Procedure

Upon recruitment for this study, participants were requested not to smoke, clean their teeth, eat or drink anything except water for 2 hours prior to the study to minimise the risk that their taste perception of the fats would be contaminated. A 10ml sample of corn oil was presented in a small opaque plastic cup. Participants were unaware as to the identity of the sample. A standard "sip-and-spit" procedure was employed, in which, after tasting, participants were required to expectorate and complete the relevant sensory rating scales. After rinsing with distilled water, participants then completed the food frequency questionnaire and questionnaires relating to their weight control history. Their height and weight was also measured and recorded.

Analysis

Pearson's correlation analysis was applied to examine the relationship between perceived taste characteristics and preferences for corn oil and reported consumption of individual fat-containing foods. Principal components analysis was also applied to attempt to reduce the individual foods into categories. One-way ANOVAs were used to investigate the relationship between predominant taste quality perceived in corn oil and intake of specific fat-containing foods. Independent samples t-tests were applied to examine the effect of whether an individual was currently dieting upon their taste perceptions and preferences for corn oil. Pearson's correlation analysis was applied to investigate the relationships between Body Mass Index (BMI), dieting frequency and success and taste responses to corn oil.

Results

Correlations between taste responses to corn oil

Due to the fact that taste responses to corn oil were unlikely to be uncorrelated and that this would have an effect when interpreting the relationship between specific taste qualities and consumption of foods, Pearson's correlation analysis was carried out. Significance levels were adjusted using Bonferroni's correction, as appropriate for multiple comparisons. Results can be seen in the correlation matrix in *Table 12*:

Table 14: Correlations between taste qualities perceived in corn oil

	Sweetness	Saltiness	Sourness	Bitterness	Intensity	Taste preference	Texture preference
Sweetness		r = 0.354 NS	r = 0.369 NS	r = 0.255 NS	r = 0.327 NS	r = 0.526 p<0.05	r = 0.431 p<0.05
Saltiness	r = 0.354 NS		r = 0.680 p<0.05	r = 0.719 p<0.05	r = 0.299 NS	r = 0.261 NS	r = 0.180 NS
Sourness	r = 0.369 NS	r = 0.680 p<0.05		r = 0.793 p<0.05	r = 0.465 p<0.05	r = 0.178 NS	r = 0.074 NS
Bitterness	r = 0.255 NS	r = 0.719 NS	r = 0.793 NS		r = 0.422 NS	r = 0.197 NS	r = 0.134 NS
Intensity	r = 0.327 NS	r = 0.299 NS	r = 0.465 NS	r = 0.422 NS		r = 0.130 NS	r = 0.075 NS
Taste preference	r = 0.526 p<0.05	r = 0.261 NS	r = 0.178 NS	r = 0.197 NS	r = 0.130 NS		r = 0.635 p<0.05
Texture preference	r = 0.431 p<0.05	r = 0.180 NS	r = 0.074 NS	r = 0.134 NS	r = 0.075 NS	r = 0.635 p<0.05	

NS = Non-significant

The relationship between taste responses to corn oil and intake of fat-containing foods

The following results were revealed when Pearson's correlation analysis was carried out between taste qualities perceived in corn oil and intake of each fat-containing food. Bonferroni's correction was applied for multiple comparisons.

Sweetness

Significant positive correlations were found between perceived sweetness of corn oil and self-reported consumption of biscuits ($r = 0.23$, $p<0.05$), cheddar cheese ($r = 0.24$, $p<0.05$), dark chocolate ($r = 0.26$, $p<0.05$) and margarine ($r = 0.26$, $p<0.05$). A significant negative correlation was found between perceived sweetness of corn oil and intake of fish and chips ($r = -0.27$, $p<0.05$).

Saltiness

No significant correlations were found between perceived saltiness of corn oil and self-reported consumption of any fat-containing food.

Sourness

Significant positive correlations were found between perceived sourness of corn oil and reported consumption of biscuits ($r = 0.22$, $p<0.05$) and taramasalata ($r = 0.24$, $p<0.05$).

Bitterness

No significant correlations were found between perceived bitterness of corn oil and estimated intake of any fat-containing food.

Intensity

A significant negative correlation was found between perceived intensity of corn oil and self-reported consumption of peanut butter ($r = -0.26$, $p<0.05$).

Taste preference

Significant negative correlations were found between preference for the taste of corn oil and consumption of butter (r = -0.25, $p<0.05$) and chips (r = -0.25, $p<0.05$). Significant positive correlations were found with estimated intake of cream crackers (r = 0.39, $p<0.001$) and yoghurt (r = 0.28, $p<0.05$).

Texture preference

Significant positive correlations were found between hedonic rating for the texture of corn oil and reported intake of bacon (r = 0.24, $p<0.05$), cream crackers (r = 0.42, $p<0.001$) and duck (r = 0.25, $p<0.05$).

Principal components analysis was applied to the fat-containing foods listed on the food frequency questionnaire but a meaningful solution could not be reached.

The relationship between predominant taste quality perceived in corn oil and intake of fat-containing foods

On the basis of taste quality perceived most strongly in corn oil, 24 (30%) individuals were classified as sweet tasters, 21 (26.3%) as salty tasters, 14 (17.4%) as sour tasters and 21 (26.3%) as bitter tasters.

Mean self-reported consumption of each fat-containing food relating to predominant taste quality perceived in corn oil can be seen in *Table 15*:

Table 15: Mean estimated consumption ratings of fat-containing foods relating to predominant taste quality perceived in corn oil

		Predominant taste quality perceived in corn oil ("taster group")			
	Food	Sweet	Salty	Sour	Bitter
Mean intake	Avocado	1.25	1.57	1.64	1.38
±		0.44	0.93	0.93	0.59
Mean intake	Bacon	3.25	2.62	3.36	3.24
±		1.73	1.20	1.55	1.41
Mean intake	Beef	2.46	3.10	3.07	3.19
±		1.32	1.48	1.59	1.37
Mean intake	Burgers	2.58	3.00	2.57	2.86
±		1.41	1.27	1.45	1.46
Mean intake	Biscuits	5.46	4.81	4.64	5.38
±		1.81	2.04	2.24	2.06
Mean intake	Brie	2.13	1.67	2.07	2.00
±		0.95	0.86	0.92	1.38
Mean intake	Butter	3.25	3.86	3.43	3.81
±		2.11	2.31	2.71	2.70
Mean intake	Cakes	4.38	4.05	4.29	4.57
±		1.58	1.36	1.38	1.36
Mean intake	Cheddar	5.42	4.29	5.64	4.81
±	cheese	1.18	1.93	1.01	1.83
Mean intake	Chicken	4.33	4.33	4.21	4.67
±		1.47	1.46	1.97	1.46
Mean intake	Chips	3.67	4.38	4.00	4.14
±		1.27	1.16	1.52	1.35
Mean intake	Coconut	1.83	1.86	1.86	2.00
±		0.76	0.57	0.86	0.84
Mean intake	Cream	2.33	2.57	2.36	2.67
±		0.87	1.21	0.75	1.39
Mean intake	Cream cheese	2.67	2.05	2.43	3.05
±		1.27	1.28	1.28	2.01
Mean intake	Cream	2.88	2.24	2.57	2.48
±	crackers	1.26	1.14	1.34	1.37
Mean intake	Crème fraiche	1.92	1.81	1.79	1.52
±		1.02	1.12	1.05	0.60
Mean intake	Crisps	4.58	4.29	4.79	4.38
±		1.61	1.82	2.05	1.60
Mean intake	Croissants	2.54	2.38	2.57	4.86
±		1.10	1.47	1.34	11.52
Mean intake	Curries	3.33	3.76	3.21	3.24
±		1.31	1.58	1.37	1.41
Mean intake	Custard	2.50	2.10	2.43	2.62
±		1.02	1.14	1.07	0.83
Mean intake	Dark	2.42	2.10	2.29	1.76
±	chocolate	0.97	1.14	1.07	0.83

	Food	Predominant taste quality perceived in corn oil ("taster group") Sweet	Salty	Sour	Bitter
Mean intake	Donuts	2.50	2.33	2.14	2.29
±		1.02	1.02	0.54	1.01
Mean intake	Duck	1.75	1.57	1.29	1.48
±		0.99	0.81	0.61	0.75
Mean intake	Eggs	4.58	4.00	4.71	3.95
±		0.93	1.52	1.49	1.69
Mean intake	Fish and chips	2.96	3.19	2.93	3.19
±		1.43	1.33	1.44	1.29
Mean intake	Fried rice	2.50	2.76	2.57	2.95
±		1.22	1.18	1.51	1.16
Mean intake	Fried	2.04	2.52	2.00	2.38
±	breakfast	1.08	1.12	1.11	1.24
Mean intake	Fromage frais	1.88	2.14	2.14	1.86
±		0.80	0.96	1.35	1.01
Mean intake	Ice cream	3.29	3.24	3.34	3.24
±		1.27	1.09	1.60	1.26
Mean intake	Lamb	2.29	2.76	3.07	3.06
±		1.27	1.22	1.21	1.31
Mean intake	Margarine	6.63	4.81	6.36	4.62
±		1.81	2.75	2.56	2.64
Mean intake	Marscarpone	1.33	1.19	1.29	1.38
±	cheese	4.82	0.51	0.47	092
Mean intake	Mayonnaise	3.08	3.14	4.86	3.48
±		1.86	1.65	2.18	1.83
Mean intake	Milk	5.04	4.81	5.00	5.00
±	chocolate	1.88	1.66	0.96	1.79
Mean intake	Peanuts	2.71	3.00	2.93	2.38
±		1.23	1.34	1.33	1.02
Mean intake	Peanut butter	1.75	1.95	2.00	1.53
±		0.94	1.28	1.84	0.51
Mean intake	Pesto	1.83	1.90	2.00	2.00
±		1.27	1.14	1.57	1.34
Mean intake	Pizza	3.50	3.33	3.86	3.57
±		1.18	1.07	0.86	1.03
Mean intake	Popcorn	2.25	1.95	2.14	2.38
±		0.68	0.97	0.86	0.92
Mean intake	Pork	2.50	3.00	3.07	2.95
±		1.22	1.55	1.14	1.69
Mean intake	Roast dinner	2.92	3.62	3.93	3.57
±		1.44	1.36	1.27	1.29
Mean intake	Salad dressing	2.58	3.29	3.93	2.76
±		1.61	1.82	1.59	1.51
Mean intake	Sausages	3.21	2.90	3.14	3.38
±		1.67	1.61	1.51	1.40
Mean intake	Savoury pies	2.79	3.14	2.57	3.24
±		1.64	1.71	1.45	1.45

		Predominant taste quality perceived in corn oil ("taster group")			
	Food	Sweet	Salty	Sour	Bitter
Mean intake	Semi	6.17	6.00	6.24	6.05
±	skimmed milk	3.07	2.76	3.13	2.82
Mean intake	Skimmed	3.54	2.95	3.86	2.95
±	milk	3.13	2.64	3.42	2.69
Mean intake	Sour cream	1.42	1.48	1.36	1.33
±		0.58	0.75	0.84	0.58
Mean intake	Stilton	1.58	1.57	1.64	1.62
±		0.72	0.93	0.84	0.87
Mean intake	Sweet pies	2.71	2.62	2.79	2.81
±		1.20	1.07	1.42	1.40
Mean intake	Taramasalata	1.17	1.43	1.57	1.48
±		0.38	0.75	0.94	0.98
Mean intake	White	1.83	2.52	2.50	2.29
±	chocolate	0.92	1.25	1.70	0.96
Mean intake	Whole milk	2.17	2.52	1.79	2.14
±		1.99	2.06	1.85	1.91
Mean intake	Yoghurt	4.63	4.14	3.57	3.95
±		2.08	1.68	195	2.16

One-way ANOVAs were carried out to examine the relationship between predominant taste quality perceived in corn oil and consumption of each fat-containing food. Mean values indicate that sweet taste responders reportedly consumed margarine more frequently. Bonferroni's post-hoc analysis also revealed that the significant main effect for mayonnaise was related to differences between sweet and sour taste responders, with those perceiving corn oil to taste predominantly sour reportedly consuming mayonnaise more frequently. Despite the significant main effect, pairwise analysis revealed no significant differences for cheddar cheese. However, mean values indicate that sweet and sour taste respondents reported consuming the food most frequently, whilst those who perceived corn oil to be predominantly salty ate cheddar least often.

The relationship between taste responses and frequency of consumption for corn oil

Pearson's correlation analyses were carried out between taste responses to corn oil stimuli and self-reported use and dietary consumption of corn oil. No significant relationships were found between regular use of corn oil and basic taste qualities perceived or taste preference for the corn oil stimuli. However, a significant negative correlation was found between frequency of intake and perceived intensity of corn oil ($r = -0.24$, $p<0.05$), whilst a significant positive correlation was found between consumption and preference for the texture of corn oil ($r = 0.24$, $p<0.05$).

One-way ANOVA was carried out between predominant taste quality perceived in corn oil and self-reported frequency of intake. No significant differences were found.

The relationship between taste responses to corn oil, Body Mass Index and dieting behaviour

Body Mass Indices (BMI) ranged from 16.45 to 39.26. The mean BMI was 24.8, with a standard deviation of 4.84.

65 participants (81.3%) reported that they were not currently dieting at the time of study, whilst 15 (18.8%) stated that they were dieting to lose weight. Mean taste responses to corn oil stimuli relating to whether the participant was dieting at the time of testing can be seen in *Table 16*:

Table 16: Mean taste responses to corn oil relating to dieting status

	Taste qualities	Currently dieting	
		Yes	No
Mean	Sweetness	19.46	19.49
±		25.02	23.42
Mean	Saltiness	17.60	16.60
±		23.55	17.91
Mean	Sourness	20.47	16.15
±		21.79	22.71
Mean	Bitterness	16.80	17.14
±		23.19	21.48
Mean	Intensity	37.20	28.02
±		31.68	22.03
Mean	Taste preference	14.87	17.08
±		14.71	17.87
Mean	Texture preference	18.53	23.06
±		15.57	22.32

Mean values indicated that dieters appeared to perceive the corn oil stimuli as tasting more intense and also reported decreased preferences compared to non-dieters. Differences between the ratings for the four basic taste qualities were very small.

Independent samples t-tests were carried out and revealed no statistically significant differences between dieters and non-dieters in their taste responses to corn oil.

49 (61.2%) of participants reported that they dieted to lose weight at some time, whilst 31 (38.8%) stated that they never dieted.

Pearson's correlations were carried out between taste responses to corn oil, BMI dieting frequency and success in reaching and maintaining target weight. A significant positive correlation was found between BMI and reported frequency with which participants dieted ($r = 0.46$, $p<0.001$), whilst a significant negative correlation was found between BMI and success in maintaining target weight ($r = -0.57$, $p<0.001$). A significant positive correlation was revealed between success in reaching target weight and success in maintaining this ($r = 0.56$, $p<0.001$). A small but statistically significant negative correlation was found between success in maintaining target weight and preference for the texture of corn oil ($r = -0.34$, $p<0.05$), however no other significant relationships were found between BMI, dieting behaviour and success and taste responses to corn oil stimuli.

Discussion

As was reported in Study 1, the findings of this study also indicated a relatively high degree of correlation between the different taste qualities and preferences for corn oil stimuli. The fact that the four basic taste qualities correlated positively with each other, but also with overall intensity, may suggest that many participants who perceive a given taste quality strongly do so for all taste characteristics. This raises the question of whether individual differences actually exist between the types of taste qualities an individual perceives, or simply between the intensities. It is also interesting to note that taste preference correlated positively with sweetness and saltiness, considered to be more acceptable taste qualities in foods, but not with sourness or bitterness, often considered more aversive and undesirable qualities.

In terms of the relationship between taste qualities perceived in corn oil and self-reported intake of fat-containing foods, no significant relationships were found between consumption of foods and perceived bitterness or saltiness in the oil stimulus. However significant positive correlations were found between perceived sourness and consumption of biscuits and taramasalata. It should be noted that taramasalata was not a commonly eaten food and, therefore, differences in consumption levels were small. Significant positive correlations were also found between rated sweetness and self-reported intake of biscuits, cheddar cheese, dark chocolate and mayonnaise, whilst this taste characteristic also correlated negatively with consumption of fish and chips. This latter finding may be related to the fact that individuals who consume fish and chips more regularly also eat other savoury sources of dietary fat more frequently and are less likely to associate it with sweeter taste qualities. This hypothesis is not, however, supported by the findings of this study where no other similar negative correlations were found in other savoury fat-containing foods. In terms of the foods which correlated negatively with sweetness, all are high in fat-content and, with the exception of biscuits, fat is a very noticeable aspect of the food matrix. Dark chocolate, whilst being a type of confectionery, also has bitter taste qualities and it may be that those who are less sensitive to sweet taste characteristics would find it less palatable.

In terms of the perceived intensities and preferences for corn oil, rated intensity correlated negatively with intake of peanut butter, whilst textural preferences correlated positively with consumption of bacon and duck, both of which have relatively fatty textural qualities themselves, but also with cream crackers. Hedonic rating for the taste of corn oil correlated negatively with self-reported intake of fish and chips. This could be viewed as a surprising finding given that these foods are cooked by frying in oil, however this also provides indication that consuming fat as part of a food matrix, however obvious, is different to sampling pure processed oil alone. Both cream crackers and yoghurt correlated positively with taste preference for corn oil.

The predominant taste qualities respondents perceived in the corn oil stimulus were also related to self-reported intakes of fat-containing foods. Very few significant differences were found between fat taste descriptor groups but ANOVA did indicate that those describing corn oil as tasting predominantly sweet reported consuming more margarine and cheddar cheese. Significant differences were also revealed for mayonnaise, which sour tasters reported eating more frequently. Overall however, no discernible patterns of fat-containing food intake relating to predominant taste quality perceived in fat, could be noted. Some indication was found that sweet taste responders reported consuming a number of sweet fat-containing foods, including biscuits, dark chocolate, milk chocolate and yoghurt, more frequently than other respondents, but these variations were non-significant. Equally, these findings should be interpreted with caution due to the fact that dividing respondents into categories according to the predominant taste quality they perceive in corn oil is an experimental technique that has not been validated.

Actual frequency of use and consumption of corn oil was also examined in relation to taste responses to this fat stimulus. The results indicated that no significant relationships could be found between perception of the four basic taste qualities in corn oil and actual intake, suggesting that the taste component which appears to be present in pure processed oil does not relate to or influence its actual dietary intake. This is further supported by the fact that a significant linear relationship existed between textural preference and consumption of corn oil but no such relationship was present for taste hedonics. As was stated earlier, consuming pure processed oil alone is obviously very different to less conscious consumption when it is integrated into and disguised by the overall food matrix. However a significant negative correlation was found between overall rated intensity of corn oil and consumption, however whether this is due to infrequent intake leading to increased sensitivity or to heightened perceived intensity leading to reduced intake can only be speculated.

Overall, the above findings provide some indication that particular fat-containing foods were significantly related to both taste qualities and preferences perceived in corn oil. Therefore, experimental hypothesis 1, which stated that, "*there will be a significant relationship between taste responses to corn oil and usual dietary intake of fat-containing foods,*" can be at least partially upheld. These findings also partially replicate and build upon those of previous published research which have concluded that some relationship exists between regular dietary fat consumption and preference for fat-containing stimuli by suggesting that this may also apply to pure processed oils and may also be a function of differing perceptions of taste qualities in fat.

However, such conclusions must be regarded with some scepticism. Whilst differences have been found in dietary consumption of particular foods in relation to perceived taste qualities and preferences for oil, these are small in number and the foods for which differences were found are not consistently replicated across differing taste qualities. Equally, whilst some of these differences can be meaningfully explained, such as the significant relationship between rated sweetness of oil and intake of dark chocolate, these interpretations are still highly speculative and may of the findings remain illusive to interpretation, i.e. the positive correlation between rated intensity and consumption of cream crackers.

The failure of the principal components analysis in finding a meaningful solution of food categories also makes interpretation problematic Possible reasons for this finding are varied. It may be that the food frequency questionnaire was not a particularly accurate means of measuring food intake and that other more complex methods, such as a food diary should have been employed instead. However, as was discussed earlier, practically all measures of habitual food consumption are beset by the problem of underreporting bias (Klesges, Eck and Ray 1995; Macdiarmid and

Blundell 1998; Jonnalagadda, Benardot and Dill 2000; Goris, Meijer and Westerterp 2001) and this issue appears to be particularly pertinent when assessing fat-containing foods, as in this study (Macdiarmid and Blundell 1998; Goris, Meijer and Westerterp 2001; Vuckovic et al 2000). Therefore it may be that respondent inaccuracy was a contributory factor to the results within this study, particularly given that the food frequency questionnaire listed only "unhealthy" or "bad" food items. However, an alternative suggestion is that consumption is simply not necessarily reliably predicted by the similarity of the food types due to the range of complex additional factors influencing food intake.

Both of these hypotheses may also be used to at least partially explain why no clear or consistent relationship could be detected between consumption of fat containing foods and sensory responses to pure fat. Selection of the kinds of foods an individual chooses to consume in their daily diet is a complex area which is influenced by numerous external and internal factors in addition to taste and sensory response. The study of fat-containing foods and dietary fat in particular, is likely to bring with it a wealth of other dietary and health concerns and beliefs which will influence both food choice and intake and sensory responses. Evidence relating to underreporting bias has suggested that, even when the respondent believes that the researcher will be able to verify their dietary reports, the accuracy of these is improved but not guaranteed and underreporting remains a problem (Muhlheim et al 1998). Therefore, it is difficult to establish how this problem can be overcome or eliminated. However, it is possible that a more coherent and consistent relationship may be found by examining the relationship between fat-containing food preferences and taste responses to fat since the concerns associated with actual intake would be at least reduced. Equally, the foods examined in this particular study were of a relatively limited range particularly susceptible to underreporting (Macdiarmid and Blundell 1998; Goris, Meijer and Westerterp 2001; Vuckovic et al 2000), in that they were only fat-containing items. Thus it is possible that different or more interesting results patterns would be detected by looking at consumption of a wider range of food types and nutrients.

This study also focused upon the relationship between BMI and dieting behaviours and taste responses to pure processed oil. The findings indicated that, whilst individuals who admitted to dieting to lose weight at the time of the study demonstrated a heightened sensitivity to sourness, saltiness and overall intensity of corn oil and a reduced preference for its taste and texture, these results were non-significant. Thus whether or not an individual was dieting at the time of the study did not appear have a significant effect upon taste responses to corn oil. One possible explanation for this is that dieting may be a transient or brief state, which, whilst it may exert an influence upon sensory responses to fat, is still overridden by other more stable factors. One major difficulty with this conclusion is that the number of dieting participants was small in comparison to non-dieters, thus the differences observed may actually have been significant had a larger dieting respondent group been found.

Unsurprising and logical significant positive correlations were found between BMI and dieting frequency, whilst negative correlation was found between BMI and success in reaching target weight when dieting, indicating that the more weight an individual wishes to lose the harder they find it to reach this target. A significant positive correlation was also found between success in reaching and maintaining target weight, suggesting that the more successful an individual is in dieting the more likely they are to maintain their weight loss in the long-term.

All of these findings suggest a valid data set. However no significant relationships were revealed between taste qualities perceived in corn oil or preferences for the taste of the oil and BMI or dieting frequency or success. A small but significant negative correlation was found between success in maintaining target weight and preference for the texture of corn oil. This result suggests that success rate in maintaining a desired body weight was greater in individuals who disliked the texture of pure processed oil more, which may have been related to a reduced intake of fat. However no indication was found of a taste component to fat influencing dieting success.

On the basis of the above findings, experimental hypothesis 1, which stated, "t*here will be a significant relationship between taste responses to corn oil and Body mass Index*" can be rejected. Experimental hypothesis 3, which stated, "*there will be a significant relationship between taste responses to corn oil and dieting behaviours*" can be upheld, but only in terms of the textural properties of corn oil, as opposed to overall taste qualities. These findings can also be partially related to previous published research in that they build upon studies which reported no significant relationship between preference for fat-containing stimuli and BMI or dieting behaviours (i.e. Warwick and Schiffman 1990; Pangborn, Bos and Stern 1985).

The results of this study would suggest that the relationship between taste responses to pure fat and weight status and dieting behaviours is of little consequence. However, as was discussed earlier, it has been argued that making distinctions on the basis of current body weight may be overtly simplistic (Drewnowski 1985), and it is possible that the same applies to the measures of dieting behaviour used within this study. Whilst the methodology did take into account issues such as dieting frequency, history and long-term success, this produced only a very basic measure of restraint and did not account for specific dieting behaviour in relation to dietary fat, both of which may exert a potential influence. Equally, previous published research has suggested that neither current nor chronic dieting status were reliably associated with reported dietary intakes, suggesting that these measures may be more reflective of weight concerns than actual behaviour (French, Jeffery and Wing 1994). Therefore, it is possible that taste responses to pure fat may be related to measures such as habitual restraint, as opposed to actual dieting status or frequency.

Overall Conclusion

These findings suggest that, whilst taste components may exist within pure processed oils, they did not appear to exert a significant influence over conscious dieting behaviour and BMI. However previous research has outlined the difficulty in producing a valid measure of dieting behaviour (French, Jeffery and Wing 1994) and this may have been a contributory factor in these findings. Therefore, further research is required taking into account additional aspects of dieting behaviour, such as habitual restraint. Evidence of a relationship between perceived taste qualities and preferences for corn oil and dietary consumption of particular fat-containing foods was found but these results were, in many cases, difficult to provide a meaningful interpretation for. Equally, no real discernable pattern in types of foods or specific taste responses could be located. This does no necessarily mean that there is no relationship between dietary intake and taste responses to fat, but further research is required. It may simply be that other factors are more influential in determining dietary behaviours, dietary fat consumption and BMI, therefore the influence of taste responses to fat in its pure form is negated.

Study 7

The relationship between self-reported dietary intake, eating style, dietary restriction and taste responses to fats.

Introduction

The findings of the previous study indicated that further research was required in an attempt to clarify the relationship between taste responses to fat and body weight and dietary behaviour and consumption. The previous study focused upon dieting status, frequency and success and concluded that taste qualities and preference for pure processed oil were not significantly related. However, cognitive factors can also be regarded as playing a prominent role in dietary behaviours and no measure of these was included within the previous study.

Dietary restraint can be defined as the conscious control an individual exerts over their eating (Tepper and Ullrich 2002). High levels of dietary restraint are associated with lower reported dietary fat intakes (Laessle et al 1989; Tuschl et al 1990(a); Tuschl et al 1990(b); Tepper, Trail and Shaffer 1996) and more frequent use of reduced-fat and fat-free foods (Tepper, Trail and Shaffer 1996; Alexander and Tepper 1995; Tuorila, Kramer and Cardello 1997; Tuorila, Kramer and Engell 2001). Restraint is also reportedly higher in individuals with bulimia nervosa and anorexia nervosa, when compared with normal weight individuals (Wardle 1987) and such clinical eating groups have themselves been shown to exhibit an aversion to fat (Drewnowski et al 1987). Meanwhile, females with obesity and binge eating disorder have been found to have lower restraint levels than normal-weight controls and higher intakes of dietary fat (D'Amore et al 2001). Therefore, these findings may provide a basis for suggesting that restraint may also be associated with differing taste perception profiles for dietary fat.

Thus one aim of this study was to examine the relationship between taste responses to pure processed oils and restraint. In order to measure restraint the Dutch Eating Behaviour Questionnaire (DEBQ) was employed (Van Strien, Frijters, Bergers and Defares 1986). Several measures of restraint have been developed over recent years. These include the Restraint Scale which was hypothesised to identify unsuccessful dieters (Herman and Polivy 1980; Heatherton et al 1988) and the Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick 1985) and DEBQ (Van Strien, Frijters, Bergers and Defares 1986), both of which aim to identify successful dieters (Stunkard and Messick 1985; Van Strien, Frijters, Bergers and Defares 1986; Heatherton et al 1988). The restraint measures elicited by both the TFEQ and DEBQ appear to be relatively similar (Van Strien, Frijters, Bergers and Defares 1986). However, the DEBQ measures not only restraint, but also scales of emotional eating and external eating and it is for this reason that it was selected for use within this study.

The concept of emotional eating is derived from psychosomatic theories (i.e. Kaplan and Kaplan 1957) and concerns responding to states of emotional arousal, such as fear or anxiety, by eating, regardless of the state of hunger or internal satiety (Van Strien, Frijters, Bergers and Defares 1986). External eating can be defined as consumption in response to food-related stimuli again, regardless of the internal state of hunger or satiety (Schachter, Goldman and Gordon 1968). Such misinterpretations or disregard for the internal state when eating have been cited as causal factors in the development of obesity (Robbins and Fray 1980), however other factors such as dieting or conscious restriction also exert their influence, thus emotional and external eaters can be found with all weight groups (Van Strien, Frijters, Bergers and Defares 1986). It has also been suggested that both external and emotional eating could occur as consequences of intense dieting (Herman and Mack 1975; Herman and Polivy 1975; Polivy and Herman 1976a; 1976b). Therefore the extent to which an individual reports emotional or external eating may also be of interest in relation to taste responses to dietary fat.

Dietary intake was investigated in the previous study and indicated some inconclusive relationship between taste responses to corn oil and consumption of selected foods. However this was only in the context of fat-containing foods. Therefore a further aim of this study was to examine the relationship between taste responses to fat and a wider selection of food types in order to investigate whether, for example, individuals who reported consuming healthy foods such as green vegetables or salads on a frequent basis exhibited different taste responses to pure processed oils than individuals who did not.

The previous study also did not consider the potential influence of selecting and habitually consuming a diet which was low in fat upon taste responses to pure fats. Therefore the final aim of this study was to focus upon whether any relationship existed between taste responses to fat and reduced dietary fat intake.

Measures such as food frequency questionnaires, to assess overall dietary consumption, could be employed to gain information about the selection of a low-fat diet, however such methods have been found to be more appropriate to general eating patterns than specific nutrients. Equally, extracting the necessary information for this is complex and depends heavily upon respondents being accurate and specific enough in order to gain a valid measure. Thus, for the purpose of this study the Food Habits Questionnaire developed and validated by Kristal, Shattuck and Henry (1990) was employed. This questionnaire was developed on the basis that low-fat dietary behaviour has four basic dimensions: (a) avoidance of high-fat foods (exclusion), (b) altering commonly available foods to ensure they are lower in fat content (modification), (c) using specially formulated lower-fat foods in place of their higher-fat counterparts (substitution), and (d) using food preparation techniques or ingredients that replace common higher-fat alternatives (replacement) (Kristal, Shattuck and Henry 1990).

In order to build upon the findings of the previous study, corn oil was once again used as a representative for pure processed oil but, olive oil was also selected as an additional stimulus. Study 3 indicated that these stimuli possessed fewer properties which could be attributed to their derivative ingredients as opposed to the fat component itself. The basic taste quality labels of sweetness, saltiness and sourness were used, whilst the label burnt replaced that of bitter, as Study 3 suggested that participants preferred this descriptor. In addition the term fatty was applied, which the findings of Study 3 seemed to suggest referred to a unique fatty taste or flavour.

The following hypotheses were generated in relation to taste responses to fats and dietary consumption and restraint:

Experimental Hypothesis 1: There will be a significant relationship between taste responses to corn oil and olive oil and usual dietary intake

Experimental Hypothesis 2: There will be a significant relationship between taste responses to corn oil and olive oil and selection and consumption of a low-fat diet

Experimental Hypothesis 3: There will be a significant relationship between taste responses to corn oil and olive oil and restraint

Experimental Hypothesis 4: There will be a significant relationship between taste responses to corn oil and olive oil and emotional eating

Experimental Hypothesis 5: There will be a significant relationship between taste responses to corn oil and olive oil and external eating

Method

Design

This study employed a between subjects design. Independent variables were dietary intake of specific foods, restraint, emotionality and externality (as measured by the Dutch Eating Behaviour Questionnaire developed by Van Strien, Frijters, Bergers and Defares 1986) and fat related dietary behaviours (as measured by the Food Habits Questionnaire developed by Kristal, Shattuck and Henry 1990) Dependent variables were perceived taste qualities and preferences for pure processed oils.

Participants

50 participants were selected from the participant group used in the previous study and recruited for this study. All participants were females aged between 16 - 35 years old to control for gender and age as influencing factors. BMI ranged from 16.89 – 35.64, with a mean value of 24.54 (± 4.72). 9 (18%) participants had a BMI of <20 (categorised as below normal weight), 21 (42%) participants had a BMI within the range of 20 – 24.9 (normal weight), 13 (26%) had a BMI within the range of 25 – 29.9 (grade 1 obesity) and 7 (14%) had a BMI within the range of 30 – 39.9 (grade 2 obesity)

88% (n = 44) participants were self-reported non-smokers whilst 12% (n = 6) were smokers. 6 (12%) participants reported that they were vegetarians. No other specific dietary requirements were reported.

All participants were naïve as to the purpose of the study.

Materials

Stimuli

Sensory stimuli for this study consisted of a 10ml samples of corn oil (J. Sainsbury plc, London, UK) and olive oil (J. Sainsbury plc, London, UK). The fat was stored in a cool, dark environment, in order to minimse interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

Questionnaires

In order to rate the perceived taste qualities for the pure processed oil stimuli, participants completed response sheets containing 100mm line scales (anchored "not at all" and "extremely"). Taste qualities assessed in the oils were sweetness, saltiness, sourness, burnt and fatty. Participants were also required to record their preferences for the taste and texture of the oil stimuli, also using 100mm line scales.

Self-reported estimated intake of 86 foods and beverages was measured using a 9-category food frequency checklist (see appendix 5). The 9 categories used were "Never," "Rarely," "Once a month," "2-3 times a month," "1-2 times a week," "3-4 times a week," "5-6 times a week," "Every day" and "More than once a day."

Participants were also required to complete the Dutch Eating Behaviours Questionnaire (DEBQ) (Van Strien, Frijters, Bergers and Defares 1986) and the Food

Habits Questionnaire (Kristal, Shattuck and Henry 1990) (see appendix 5). Measurements of participant's weight and height were taken and recorded within the laboratory.

Procedure

Upon recruitment for this study, participants were requested not to smoke, clean their teeth, eat or drink anything except water for 2 hours prior to the study to minimise the risk that their taste perception of the fats would be contaminated. 10ml samples of corn oil and olive oil were presented individually in a random order in small opaque plastic cups. Participants were unaware as to the identity of the sample. Again a standard "sip-and spit" procedure was applied and, after completing the relevant sensory rating scales, participants were required to rinse three times with distilled water, spitting out each time, before repeating this procedure with the next sample. Participants were also required to take a 5-minute break between tasting and evaluating each fat sample. This was a recommended time needed to prevent the flavours of the sample being tasted being suppressed by those of the previous sample (Nguyen and Pokorny 1998). Participants then completed the food frequency questionnaires DEBQ and Food Habits Questionnaire. Their height and weight was also measured and recorded.

Analysis

Pearson's correlation analysis was applied to examine the relationship between perceived taste characteristics and preferences for each pure processed oil and reported consumption of individual foods and beverages. Principal components analysis was also applied to attempt to reduce the individual foods into categories.

Pearson's correlation analysis was applied to investigate the relationships between Body Mass Index (BMI), restraint, emotionality, externality and taste responses to each oil sample. Pearson's correlation was also employed to examine the relationship between taste responses to oils and the five dimensions of the Food Habits Questionnaire; modify meat, avoid fat as seasoning, replace fat-containing foods with other food items, substitute with lower-fat equivalents and replace fat-containing foods with fruit or vegetables (Kristal, Shattuck and Henry 1990). Where necessary, Bonferroni's adjustment for multiple comparisons was applied.

Results

Correlations between taste responses to corn and olive oils

Due to the fact that taste responses to the oils were unlikely to be uncorrelated and that this would have an effect when interpreting the relationship between specific taste qualities and consumption of foods, Pearson's correlation analysis was carried out.

In terms of relationships between the taste qualities perceived in olive oil, significant positive correlation was found between perceived sourness and "burntness", $r = 0.86$, $p<0.001$. No other significant correlations were found between any of the other taste qualities suggesting that, whilst their may have been some intersection between respondents definitions of the terms sourness and burnt, the other taste qualities were perceived as measuring separate taste qualities.

Pearson's correlation analyses were also carried out between the two oil samples. Significance levels were adjusted using Bonferroni's correction, as appropriate for multiple comparisons. The correlation matrix can be seen in *Table 17*:

Table 17: Correlations between taste responses to corn oil and olive oil

Olive oil → / Corn oil ↓	Sourness	Burnt	Saltiness	Sweetness	Fatty	Taste preference
Sourness	r = 0.63 p<0.01	r = 0.68 p<0.01	r = 0.25 NS	r = -0.14 NS	r = 0.17 NS	r = -0.03 NS
Burnt	r = 0.65 p<0.01	r = 0.70 p<0.01	r = 0.23 NS	r = -0.12 NS	r = 0.14 NS	r = -0.06 NS
Saltiness	r = 0.09 NS	r = 0.11 NS	r = 0.63 p<0.01	r = 0.01 NS	r = 0.16 NS	r = 0.26 NS
Sweetness	r = -0.18 NS	r = 0.02 NS	r = 0.29 p<0.05	r = 0.24 NS	r = -0.12 NS	r = 0.16 NS
Fatty	r = 0.03 NS	r = 0.01 NS	r = 0.13 NS	r = -0.18 NS	r = 0.91 p<0.01	r = -0.22 NS
Taste preference	r = -0.13 NS	r = -0.07 NS	r = 0.04 NS	r = -0.14 NS	r = -0.25 NS	r = 0.39 p<0.05

As can be seen from the correlation matrix, with the exception of sweetness, the perceived taste qualities between each oil sample were significantly positively correlated suggesting that common characteristics were perceived within the oils.

<u>The relationship between taste qualities perceived in pure processed oils and dietary intake</u>

Sourness

Significant positive correlations were found between perceived sourness of olive oil and consumption of dark chocolate ($r = 0.30$, $p<0.05$), hot chocolate ($r = 0.34$, $p<0.05$), stilton cheese ($r = 0.38$, $p<0.01$) and vegetarian meals ($r = 0.36$, $p<0.05$).

Significant negative correlations were found between perceived sourness of olive oil and intake of canned fish in brine ($r = -0.31$, $p<0.05$), chicken ($r = -0.35$, $p<0.05$), ham ($r = -0.28$, $p<0.05$), roast dinner ($r = -0.34$, $p<0.005$), sausage ($r = -0.41$, $p<0.005$) and turkey ($r = -0.30$, $p<0.05$).

Significant positive correlations were found between perceived sourness of corn oil and regularity of consumption of avocado ($r = 0.35$, $p<0.05$), brie ($r = 0.41$, $p<0.41$), coleslaw ($r = 0.32$, $p<0.05$), crisp bread ($r = 0.43$, $p<0.005$), diet drinks ($r = 0.41$, $p<0.005$), fruit ($r = 0.30$, $p<0.05$), hot chocolate ($r = 0.42$, $p<0.005$), nuts ($r = 0.30$, $p<0.05$), peanut butter ($r = 0.43$, $p<0.005$), pizza ($r = 0.33$, $p<0.05$), salad cream ($r = 0.40$, $p<0.01$), salad dressing (oil-based) ($r = 0.44$, $p<0.005$), skimmed milk ($r = 0.34$, $p<0.05$), stilton cheese ($r = 0.50$, $p<0.001$) and vegetarian meals ($r = 0.45$, $p<0.05$)

Significant negative correlations were revealed between perceived sourness of corn oil and intake of canned fish in brine ($r = -0.33$, $p<0.05$), chicken ($r = -0.46$, $p<0.005$), ham ($r = -0.32$, $p<0.05$), lamb ($r = -0.36$, $p<0.05$), roast dinners ($r = -0.33$, $p<0.05$) and sausage ($r = -0.41$, $p<0.005$).

Burnt

Significant positive correlations were found between the perception of a burnt taste in olive oil and intake avocado ($r = 0.31$, $p<0.05$), brie ($r = 0.32$, $p<0.05$), fruit ($r = 0.38$, $p<0.01$), fruit juice ($r = 0.40$, $p<0.005$), hot chocolate ($r = 0.44$, $p<0.005$), nuts ($r = 0.32$, $p<0.05$), pizza ($r = 0.32$, $p<0.05$), salad dressing (oil-based) ($r = 0.28$, $p<0.05$), stilton cheese ($r = 0.39$, $p<0.01$) and vegetarian meals ($r = 0.34$, $p<0.05$).

Significant negative correlations were revealed between perception of "burntness" in olive oil and intake of canned fish in brine (r = -0.28, $p<0.05$) chicken (r = -0.33, $p<0.05$), roast dinners (r = -0.29, $p<0.05$) and sausage (r = -0.34, $p<0.05$).

Significant positive correlations were found between perception of "burntness" in corn oil and consumption of avocado (r = 0.32, $p<0.05$), brie (r = 0.37, $p<0.01$), coleslaw (r = 0.31, $p<0.05$), crisp bread (r = 0.40, $p<0.005$), diet drinks (r = 0.40, $p<0.005$), fruit (r = 0.28, $p<0.05$), hot chocolate (r = 0.40, $p<0.005$), nuts (r = 0.31, $p<0.05$), peanut butter (r = 0.40, $p<0.005$), pizza (r = 0.31, $p<0.05$), salad cream (r = 0.41, $p<0.005$), salad dressing (oil-based) (r = 0.39, $p<0.01$), skimmed milk (r = 0.34, $p<0.05$), stilton cheese (r = 0.45, $p<0.005$) and vegetarian meals (r = 0.44, $p<0.005$).

Significant negative correlations were found between perception of "burntness" in corn oil and intake of canned fish in brine (r = -0.33, $p<0.05$), chicken (r = -0.45, $p<0.005$), ham (r = -0.34, $p<0.05$), lamb (r = -0.32, p<0.050, pork (r = -0.28, $p<0.05$), roast dinners (r = -0.36, $p<0.05$) and sausage (r = -0.43, $p<0.005$).

Saltiness

A significant positive correlation were found between perception of saltiness in olive oil and intake of garlic (r = 0.29, $p<0.05$).

Significant negative correlations were found between perceived saltiness of olive oil and consumption of eggs (r = -0.36, $p<0.05$), fish and chips (r = -0.33, $p<0.05$) and salad cream (r = -0.35, $p<0.05$).

Significant positive correlations were found between rated saltiness of corn oil and intakes of brie ($r = 0.49$, $p<0.001$), pasta in tomato-based sauces ($r = 0.31$, $p<0.05$), vegetarian meals ($r = 0.39$, $p<0.01$) and white chocolate ($r = 0.51$, $p<0.001$).

No significant negative correlations were revealed between perceived saltiness of corn oil and consumption of any food or beverage.

Sweetness

No significant positive correlations were found between perceived sweetness of either corn oil or olive oil and intake of any foods or drink.

Significant negative correlations were found between ratings of sweetness given for olive oil and consumption of boiled potatoes ($r = -0.44$, $p<0.005$), custard ($r = -0.31$, $p<0.05$), dark chocolate ($r = -0.35$, $p<0.05$), eggs ($r = -0.43$, $p<0.005$), honey ($r = -0.31$, $p<0.05$), pork ($r = -0.28$, $p<0.05$), salad cream ($r = -0.34$, $p<0.05$), sausage ($r = -0.40$, $p<0.005$) and stilton cheese ($r = -0.36$, $p<0.05$).

Significant negative correlations were found between perceived sweetness in corn oil and intake of custard ($r = -0.29$, $p<0.05$), pasta in cream-based sauces ($r = -0.29$, $p<0.05$) and yoghurt ($r = -0.30$, $p<0.05$).

Fatty

Significant positive correlations were found between perception of fatty flavour in olive oil and intake of alcohol ($r = 0.36$, $p<0.05$), brie ($r = 0.32$, $p<0.05$) and coleslaw ($r = 0.29$, $p<0.05$).

Significant negative correlations were found between perceived fattiness of olive oil and consumption of cakes and pastries ($r = -0.32$, $p<0.05$), chicken ($r = -0.34$, $p<0.05$), chilli ($r = -0.40$, $p<0.005$), coffee ($r = -0.35$, $p<0.01$), cream ($r = -0.31$, $p<0.05$), croissants ($r = -0.31$, $p<0.05$), curries ($r = -0.33$, $p<0.05$), fruit juice ($r = -0.35$, $p<0.05$) and lamb ($r = -0.38$, $p<0.01$).

Significant positive correlations were found between perceived fattiness in corn oil and consumption of alcohol ($r = 0.49$, $p<0.001$), brie ($r = 0.34$, $p<0.05$), margarine ($r = 0.30$, $p<0.05$) and pasta in cream-bases sauces ($r = 0.28$, $p<0.05$).

Significant negative correlations were found between rated fattiness in corn oil and intake of biscuits ($r = -0.28$, $p<0.05$), chilli ($r = -0.41$, $p<0.005$), cream ($r = -0.31$, $p<0.05$), crackers ($r = -0.31$, $p<0.05$) and fruit juice ($r = -0.29$, $p<0.05$).

Taste preferences

Significant positive correlations were found between taste preference for olive oil and intake of cream cheese ($r = 0.28$, $p<0.05$), crème fraiche ($r = 0.33$, $p<0.05$), full fat mayonnaise ($r = 0.31$, $p<0.05$), peanut butter ($r = 0.30$, $p<0.05$), salad ($r = 0.44$, $p<0.005$), skimmed milk ($r = 0.29$, $p<0.05$) and sour cream ($r = 0.60$, $p<0.001$).

Significant negative correlations were found between hedonic rating for the taste of olive oil and consumption of baked potatoes ($r = -0.34$, $p<0.05$), chicken ($r = -0.31$, $p<0.05$), croissants ($r = -0.30$, $p<0.05$), full sugar fizzy drinks ($r = -0.29$, $p<0.05$), fried rice ($r = -0.30$, $p<0.05$), pasta in cream-based sauces ($r = -0.28$, $p<0.05$) and tea ($r = -0.41$, $p<0.005$).

Significant positive correlations were found between taste preference for corn oil and intake of coffee ($r = 0.35$, $p<0.05$), cream ($r = 0.32$, $p<0.05$), crackers ($r = 0.59$, $p<0.001$), fromage frais ($r = 0.38$, $p<0.01$), pork ($r = 0.39$, $p<0.01$), salad ($r = 0.33$, $p<0.05$) and turkey ($r = 0.49$, $p<0.001$).

Significant negative correlations were found between hedonic rating for the taste of corn oil and consumption of pasta in cream-based sauces ($r = -0.31$, $p<0.05$).

An attempt was made to reduce the foods listed on the food frequency questionnaire into categories using principal components analysis but no meaningful solution could be achieved.

The relationships between selection and consumption of a low-fat diet and taste responses to each oil sample

Four dimensions of selecting a low-fat diet were derived from the Food Habits Questionnaire; (1) modifying meat, (2) avoiding fat as a seasoning, (3) replacing fat containing foods with other food items, (4) substituting fat-containing foods with reduced-fat equivalents, and (5) replacing fat-containing foods with fruit or vegetables. The greater the score for each of these dimensions, the less frequently an individual reported engaging in these fat-reducing behaviours. Descriptive statistics can be seen in *Table 18*:

Table 18: Descriptive statistics for dimensions of the Food Habits Questionnaire

Dimension	Range	Mean	Standard deviation
(1) Modify meat	0-14	6.74	±4.81
(2) Avoid fat as seasoning	5-15	10.06	±2.00
(3) Replace fat-containing foods with other foods	2-8	4.30	±1.80
(4) Substitute fat-containing foods with reduced-fat	4-19	12.88	±3.84
(5) Replace fat-containing foods with fruit/vegetable	5-12	8.90	±1.90

Dimension 1 – Modify meat

Significant negative correlations were found between dimension 1 and perceived sourness of olive oil ($r = -0.28$, $p<0.05$) and corn oil ($r = -0.39$, $p<0.01$). Significant negative correlations were also revealed with rated "burntness" of both olive oil ($r = -0.32$, $p<0.05$) and corn oil ($r = -0.38$, $p<0.01$), whilst significant negative correlations were found with perceived saltiness of corn oil ($r = -0.28$, $p<0.05$) and preference for the taste of olive oil ($r = -0.50$, $p<0.001$).

Dimension 2 – Avoid fat as seasoning

A significant negative correlation was found between perceived sweetness of olive oil and dimension 2 ($r = -0.36$, $p<0.01$). No other significant relationships were revealed.

Dimension 3 – Replace fat-containing foods with other foods

Significant negative correlations were found between dimension 3 and perceived sourness of olive oil ($r = -0.39$, $p<0.01$) and corn oil ($r = -0.50$, $p<0.001$), perceived "burntness" of olive oil ($r = -0.40$, $p<0.005$) and corn oil ($r = -0.50$, $p<0.001$), perceived saltiness of olive oil ($r = -0.40$, $p<0.005$) and corn oil ($r = -0.36$, $p<0.05$) and rated fattiness of olive oil ($r = -0.31$, $p<0.05$).

Dimension 4 – Substitute fat-containing foods with reduced-fat items

Significant negative correlations were revealed between dimension 4 and rated sourness ($r = - 0.30$, $p<0.05$) and burntness ($r = -0.50$, $p<0.001$) of corn oil. Significant negative correlations were also found between perceived saltiness of both olive oil ($r = -0.32$, $p<0.05$) and corn oil ($r = -0.34$, $p<0.05$) and perceived sweetness ($r = -0.32$, $p<0.05$) and fattiness ($r = -0.29$, $p<0.05$) of olive oil.

Dimension 5 – Replace fat-containing foods with fruit and vegetables

A significant negative correlation was revealed between dimension 5 and perceived "burntness" of olive oil ($r = -0.30$, $p<0.05$), whilst a significant positive correlation was found with rated fattiness of corn oil ($r = 0.30$, $p<0.05$).

The relationships between Body Mass Index (BMI), restraint, emotional eating, external eating and taste responses to each oil sample

BMI ranged from 16.89 – 35.64, with a mean value of 24.54 (± 4.72). Scores for restraint, emotional eating and external eating were calculated using the scoring system described in the original publication (Van Strien, Frijters, Bergers and defares 1986). Scores for restraint ranged from 1.10 – 5.00, with a mean value of 2.82 (± 0.96). Emotional eating scores ranged from 1.38 – 5.00, with a mean value of 2.89 (± 0.94). External eating scores ranged from 1.38 – 5.00, with a mean value of 3.38 (± 0.69).

A significant positive correlation existed between BMI and emotional eating ($r = 0.33$, $p<0.05$). No significant correlations existed between restraint, external eating or emotional eating. Correlations were carried out between BMI, restraint, emotional and external eating and the taste qualities perceived in olive oil and corn oil. A significant positive correlation was revealed between perceived sourness of olive oil and emotional eating ($r = 0.36$, $p<0.05$). No significant relationships were found for perceived saltiness or burntness of either oil. A significant negative correlation was found between BMI and perceived sweetness of olive oil ($r = -0.32$, $p<0.05$), whilst significant positive correlations were revealed between restraint and rated sweetness of both olive oil ($r = 0.40$, $p<0.005$) and corn oil ($r = 0.32$, $p<0.05$). Significant negative correlations were also revealed between restraint and perceived fattiness of both olive oil ($r = -0.28$, $p<0.05$) and corn oil ($r = -0.31$, $p<0.05$). A significant positive correlation was found between restraint and preferences for corn oil ($r = 0.33$, $p<0.05$).

Discussion

The findings of this study indicated that, with the exception of significant positive correlations between the taste labels sour and burnt, no significant inter-relationships were revealed between the taste qualities of either corn oil or olive oil. This significant relationship between sour and burnt replicates the findings of earlier studies (i.e. Study 6), which indicated a significant linear relationship between taste descriptors sour and bitter (replaced by the label burnt in this study). This suggests that these two taste qualities are perceived as being closely related. Results also indicated that taste descriptors, with the exception of sweetness, were positively correlated between corn oil and olive, suggesting that the two pure processed oils were perceived as having similar taste characteristics.

In terms of the relationship between dietary intake and taste responses to fats, a wide range of varying foods and beverages were significantly related to perception of different taste qualities and preference for corn oil and olive oil. These included cheese, meats, chocolate and desserts, salad cream and dressings, fruit, salad and vegetables, fish, curries, chilli, pasta, bread and crackers, coffee, alcohol and soft drinks. Corn oil tended to correlate significantly with a slightly larger number of foods, but overall, intake for the majority of foods showed a consistent relationship with taste qualities for both fat samples. Detectable patterns could also be observed across food types in their relationship to taste responses with pure processed oils.

A particularly noticeable relationship was the fact that meats and meat products, i.e. sausages, correlated negatively with perceived sourness, burntness, sweetness and fattiness. This suggested that individuals who consumed more meat did not perceive these taste characteristics in pure fat to be as intense as those who consumed a diet containing less meat products. Interestingly, this relationship could not be demonstrated for perceived saltiness. However, overall the other foods which correlated negatively with each of the perceived taste qualities, with the exception of fattiness, also tended to be less healthy, i.e. fish and chips, pasta in cream-based sauces, custard. Equally, the foods and beverages whose consumption correlated positively with the taste characteristics perceived in pure processed oils tended to be considered healthier, i.e. vegetarian food, fruit and vegetables, skimmed milk, nuts, fruit juice, garlic and "dieting" products such as reduced-sugar soft drinks and crisp bread. Salad dressings also tended to correlate positively with the intensity of taste qualities perceived in the oils and, whilst these are fat-based this could also be seen as indicating an increased consumption of salads. Thus it may be that those who consume a diet higher in fat and considered less healthy may also perceive fat itself to taste less intense. However whether this is a contributory factor in maintaining their diet or a consequence of it is less clear.

Perception of a unique fatty flavour in pure processed oil exhibited a slightly different relationship with food intakes, when compared to the other taste characteristics. It was found to be negatively correlated to cream, fruit juice, chilli, curries and meats. This is interesting in that preference for these foods has also been reported in previous published research to be negatively related to sensitivity to PROP (Forrai and Bankovi 1984; Duffy and Bartoshuk 2000; Bartoshuk et al 1994; Tepper and Nurse 1997), which has itself been linked to sensitivity to fat. Therefore these findings may be, at least partially, suggestive of genetic PROP taster status. Perceived sweetness in the pure processed oil samples also related in an interesting way to consumption of particular foods. Significant negative correlations were found with intake of sweet foods such as custard, fruit yoghurt, honey and chocolate. Thus it could be suggested that individuals who consume foods with added sucrose more frequently were less likely to be able to detect sweet taste qualities in pure fats than respondents who ate these foods less often.

Overall, these findings suggest that taste responses to pure processed oils do appear to be related to general dietary consumption. As in Study 6, Principal Components Analysis failed to reduce the foods into meaningful categories, again suggesting that individuals do not necessarily allow food groups to be a major influence upon their diet. However examination of the results shows definite patterns in the foods which correlate in a given way to the perceived taste qualities in the fat stimuli and, whilst some of these may be difficult to interpret, logical hypotheses can be provided for the majority. Thus, on the basis of these findings, experimental hypothesis 1, which stated, "*there will be a significant relationship between taste responses to corn oil and olive oil and usual dietary intake*" can be accepted.

As has been previously discussed, food choice and consumption is a complex issue influenced by multiple factors. From the findings of this study it would appear that, whilst there is no clear and definite relationship between consumption of fat-containing foods and taste responses to pure fat, the latter can be related to some degree to overall dietary composition. However, what it is less clear is whether individuals' sensory responses to pure fats are a causal factor in influencing their dietary selection or a consequence of it. Further work also needs to be carried out to replicate and clarify these findings. The use of food frequency questionnaires has provided valid and useful data both within this study and previous published research (Block 1982), however further clarification could be sought through the use of more sophisticated methods possibly incorporating biochemical measures as a means of validity.

It is interesting to note that a number of the food items found to be significantly related to taste responses to fats were fat-containing items replicated from the food frequency questionnaire used in the previous study. This could be reflective of evidence suggesting that individuals are less willing to report accurate consumption of "bad" or unhealthy foods (Macdiarmid and Blundell 1998; Vuckovic et al 2000; Goris, Meijer and Westerterp 2001). The presence of healthier items, such as salad, fruit and vegetables may have made respondents more willing to admit to eating fat-containing foods as well.

Within this study, the findings from the Food Habits Questionnaire, is a means of building upon results from the food frequency questionnaire. The greater the score for each dimension on this questionnaire, the less frequently an individual reported engaging in the dietary fat-reducing habits. Negative correlations with specific taste qualities were found across dimensions for both oil samples, thus these results indicated overall that individuals who reported selecting and consuming a reduced-fat diet perceived given taste qualities with olive oil and corn oil as being more intense than those whose diet was higher in dietary fat. Therefore these findings support and build upon those reported within the food frequency questionnaire for overall diet and experimental hypothesis 2, which stated, "*there will be a significant relationship* *between taste responses to corn oil and olive oil and selection and consumption of a low-fat diet*" can also be upheld.

However, it must be taken into account that not all taste qualities were significantly negatively correlated with all dimensions. Dimension 2 (avoiding fat as a seasoning) correlated negatively with rated sweetness of olive oil but with no other taste characteristics. This could be explained by the fact that the questionnaire defined using fat as a seasoning in terms of applying butter or margarine to foods, as opposed to pure processed oils, and, as was demonstrated in Study 1, the taste qualities of these two forms of fat differ significantly. Therefore the dimension is less likely to affect or be related to taste qualities perceived in oils. Taste preferences for both corn oil and olive oil failed to correlate significantly with any of the fat-reduction dimensions. This, alongside the findings from the food frequency questionnaire relating to taste preference for oils, suggests that taste preference for pure fat does not appear to be strongly related to overall diet or dietary fat intake.

In addition to dietary composition, this study also focused upon restraint as a potentially relating factor to taste responses to pure processed oils. The findings revealed that restraint correlated negatively with perceived fattiness for both corn and olive oils. This suggests that the more restrained an individual was, the less fatty they perceived the pure processed oil to be. This is somewhat surprising given that a restrained individual may be less likely to consume dietary fat and therefore, on the basis of earlier findings in this study, perceived it as being more intensely fatty. Further results relating to restraint also indicated that restraint was positively correlated with rated sweetness for both oil samples and with taste preference for corn oil. The finding relating to sweetness would seem to be inconsistent with that relating to fattiness, suggesting that the earlier hypothesis that individuals do not necessarily perceive fat as having differing taste qualities, but simply detect all taste qualities as being more, or less, intense, does not apply to restraint. Equally, the findings relating to taste preference for corn oil also appear paradoxical in that high levels of dietary restraint are associated with lower reported dietary fat intakes (Laessle et al 1989; Tuschl et al 1990(a); Tuschl et al 1990(b); Tepper, Trail and Shaffer 1996) and more frequent use of reduced-fat and fat-free foods (Tepper, Trail and Shaffer 1996; Alexander and Tepper 1995; Tuorila, Kramer and Cardello 1997; Tuorila, Kramer and Engell 2001).

On the basis of these findings, experimental hypothesis 3, which stated that "*there will be a significant relationship between taste responses to corn oil and olive oil and restraint*" can be accepted despite the fact that the findings are not necessarily in the direction which may have been expected. However they can be related to previous published research. Lahteenmaki and Tuorila (1995) reported that some diet-restrained females reported a heightened preference for high-fat foods, yet still reported frequent consumption of reduced-fat food. Therefore it appears that restrained eaters are actually guided more strongly by weight concerns than taste when selecting the foods they choose to eat, thus their taste preferences for and perceptions of pure fats may not necessarily lead to increased consumption of dietary fats. This could also be the case with eating disordered individuals who, on the basis of these findings related to restraint, may not necessarily demonstrate differing perceptions of taste qualities or even taste preferences for pure fats, but whose cognitive concerns regarding weight gain would still prevent them from consuming foods in a manner based upon their taste responses.

In terms of the other two dimensions from the DEBQ, findings revealed that external eating failed to relate significantly to any of the taste responses for either oil sample. Thus experimental hypothesis 5, which stated, "*there will be a significant relationship between taste responses to corn oil and olive oil and external eating*" is rejected on the basis of this. Emotional eating was found to be significantly positively correlated to rated sourness of olive oil but no other significant relationships were revealed. Thus, in theory experimental hypothesis 4, which stated "*there will be a significant relationship between taste responses to corn oil and olive oil and emotional eating*" can be accepted. However in reality it is clear that, on the basis of these findings, the relationship between emotionality and taste responses to fats is not a noteworthy one. Similar explanations may apply to these findings as to those proposed for restraint in that, both externality and emotionality are cognitive concerns. Thus it would appear that they are unrelated to taste responses to pure fats and may even mask these when decisions about food consumption are to be made.

BMI was found to be significantly negatively correlated with perceived sweetness of olive oil but no other significant relationships were revealed. This finding is in keeping with that from Study 6, which suggested that taste responses to pure processed oils did not appear to be of importance in relating to or determining BMI. It seems likely that the relationship between these factors is masked by other, more pertinent factors.

Chapter 8

The relationship between self-reported dietary preferences and taste responses to fats.

Study 8

The relationship between self-reported preference for fat-containing foods and taste responses to fats

Introduction

The previous chapter focused upon the relationship between self-reported food intake and taste responses to fat. However, research has indicated that, whilst a link clearly exists between food intake and specific food preferences, it is inappropriate to assume that one factor is simply a reflection of the other due to the numerous other personal, social and contextual issues which also exert their influence (Pangborn and Giovanni 1984; Reed et al 1997; Nestle et al 1998). The preference for fat-rich foods in humans has been linked to physiological, genetic and learned factors (Schiffman et al 1998). However the relationship between food preferences and sensory responses to fat has been all but ignored by previous research, with most studies choosing to focus upon dietary intake instead (i.e. Mela and Sacchetti 1991; Pangborn, Bos and Stern 1984). Fisher and Birch (1995) examined differences in preferences for high-fat foods and dietary fat in 3-5 year old children. Results indicated that, despite the children being offered identical menus over the same 30-hour time period, fat intake ranged from 25% - 45% and those exhibiting the strongest preferences for high fat foods also had a higher usual fat intake that those with lower preferences. However, this study in no way addressed the relationship between the specific sensory appeal held by fats and overall food preferences. Equally, it should be taken into account that the participants were very young children and that, as individuals grow older it is possible that the relationship between food preferences and responses to fat may become very different from that of actual food consumption with the increasing influence of additional factors such as dieting concerns, etc.

Previous published research has indicated that preferences for basic sweet or salty solutions does not necessarily relate to liking for more complex sweet or salty foods (Lucas and Bellisle 1987; Mattes 1985; Pangborn and Pecore 1982). Likewise, it is possible that preferences for pure fats do not relate to hedonic responses to fat-containing foods, but this has yet to be tested by previous published research. The suggestion, derived from informal unpublished reports by Gilbertson et al (1997; 1998), that individual differences may exist in taste responses to fat raises the possibility that this may differ depending upon hedonic response to fat-containing foods and may also be related to the specific types of fat-containing foods and sources of dietary fat an individual enjoys. For example, an individual who prefers sweet sources of fat, i.e. ice cream, may exhibit different taste responses to pure fat to an individual who prefers savoury or salty fat sources, i.e. chips, crisps. Studies 6 and 7, which addressed dietary consumption, indicated that, whilst a relationship did appear to exist between the foods an individual chose to consume and the taste qualities they ascribed to pure processed oils, the link was not so clearly defined. However, although dietary consumption may provide some applicable information, a full understanding can only be gained by investigating actual self-reported preferences since factors such as dieting concerns, etc, may prevent an individual from consuming a food type they actually enjoy. This issue is particularly pertinent in the case of fat-containing foods and was illustrated in Study 7 by the findings that restrained individuals actually exhibited heightened preferences for pure processed oils.

The aim of this study was to investigate the relationship between preferences for fat-containing foods and taste responses to pure processed oil. In order to assess whether particular types or sources of dietary fat could be linked to specific taste responses to oil a food preference questionnaire was used which listed the same 53 fat-containing foods as were examined in Study 6. 100mm line-scales were used to measure hedonic ratings for each food item. This method was felt to be the most appropriate as it provided a continuum of preference without requiring respondents to categorise their liking into artificially-produced groups. Further advantages to this method also included its simplicity, thus allowing individuals to give their initial response and minimising the need for scrutiny which may have resulted in altered ratings, the fact that respondents could respond meaningfully with minimum training and that it provided meaningful preference data. Since no previous published research had been carried out in this area, it was deemed appropriate to use the basic responses of sweet, salty, sour and bitter as taste initial descriptors for the oil.

As has been previously discussed, a major difficulty in examining individuals' taste responses to fat is that it tends to be disguised by the specific properties of the foods it is present in. However most foods can be simply categorised by a predominant taste descriptor, i.e. sweet, salty, savoury, etc. A further aim of this study was to examine whether individual's were able to label oil as having a predominant basic taste quality (sweet, salty, sour or bitter) and, if so, whether this related to their food preferences.

As in Study 6, the fat stimulus selected for this was corn oil, since it was found in Study 3 to be the processed oil most representative of a "fatty" flavour, probably due to the fact that its derivative was not as intense in taste as oils such as walnut oil.

For the purpose of this study, the following hypotheses were generated:

Experimental hypothesis 1: There will be a significant relationship between taste responses to fat and preferences for fat-containing foods

Experimental hypothesis 2: There will be a significant relationship between predominant taste quality perceived in oils and preferences for fat-containing foods.

Method

Design

This study employed a correlational design between two sets of variables; self-reported preferences for fat-containing foods and perceived taste qualities and preferences for corn oil. An independent between subjects design was also employed. The independent variable was predominant taste quality perceived in oil, whilst the dependent variables were self-reported preferences for 53 fat-containing foods

Participants

80 participants were recruited for this study. They were the same participant group who had previously taken part in Studies 4 and 5. 49% (n = 39) of these participants had also previously taken part in Studies 1 and 2. All participants were female and aged between 16-35 in an attempt to control for age and gender related influences. 79% (n = 63) were self-reported non-smokers whilst 21% (n = 17) were smokers. 11% (n = 9) reported that they were vegetarians. No other specific dietary requirements were reported.

All participants were naïve as to the purpose of the study.

Materials

Stimuli

Sensory stimuli for this study consisted of 10ml samples of corn oil (J. Sainsbury plc, London, UK) and sunflower oil (J. Sainsbury plc, London, UK). The fats were stored in a cool, dark environment, in order to minimse interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

Questionnaires

In order to rate the perceived taste qualities and preferences for corn oil, participants completed response sheets (see appendix 1) containing 100mm line scales on which they indicated their rating of the stimuli's sweetness, saltiness, sourness, bitterness and liking for taste and texture (all anchored "not at all" and "extremely") and perceived flavour strength (anchored "barely detectable" and "strongest imaginable"). Participants were also required to record the taste quality they perceived to be most dominant, given a choice of sweet, salty, sour and bitter.

Self-reported preferences for 53 fat-containing foods was measured using 100mm line scales anchored "not at all" (0mm) and extremely (100mm) (see appendix 6).

Procedure

Upon recruitment for this study, participants were requested not to smoke, clean their teeth, eat or drink anything except water for 2 hours prior to the study to minimise the risk that their taste perception of the fats would be contaminated. A 10ml sample of corn oil was presented in a small opaque plastic cup. Participants were unaware as to the identity of the sample. A standard "sip-and-spit" procedure was employed, in which, after tasting, participants were required to expectorate and complete the relevant sensory rating scales, in addition to indicating which taste quality they perceived most strongly in the oil. After rinsing with distilled water, participants then completed the food preference questionnaire.

Analysis

Pearson's Correlation analysis was used to examine the relationship between taste qualities and preferences perceived in corn oil and preferences for each fat-containing food. Bonferroni's correction for multiple comparisons was applied. Individuals were also classified as sweet, salty, sour or bitter tasters, depending on the quality they perceived most strongly in the corn oil. One-way Analyses of Variance were performed between "fat taster status" and hedonic rating for each food. Factor analysis was also used in an attempt to reduce the 83 fat-containing foods rated for preference into a smaller number of meaningful food categories.

Results

Correlations between taste responses to corn oil

Due to the fact that taste responses to corn oil were unlikely to be uncorrelated Pearson's correlation analysis was carried out. Pearson's correlation analysis was carried out. Significance levels were adjusted using Bonferroni's correction, as appropriate for multiple comparisons. Results can be seen in the correlation matrix in *Table 19*:

Table 19: Correlations between taste qualities perceived in corn oil

	Sweetness	Saltiness	Sourness	Bitterness	Intensity	Taste preference	Texture preference
Sweetness		r = 0.354 NS	r = 0.369 NS	r = 0.255 NS	r = 0.327 NS	r = 0.526 $p<0.05$	r = 0.431 $p<0.05$
Saltiness	r = 0.354 NS		r = 0.680 $p<0.05$	r = 0.719 $p<0.05$	r = 0.299 NS	r = 0.261 NS	r = 0.180 NS
Sourness	r = 0.369 NS	r = 0.680 $p<0.05$		r = 0.793 $p<0.05$	r = 0.465 $p<0.05$	r = 0.178 NS	r = 0.074 NS
Bitterness	r = 0.255 NS	r = 0.719 NS	r = 0.793 NS		r = 0.422 NS	r = 0.197 NS	r = 0.134 NS
Intensity	r = 0.327 NS	r = 0.299 NS	r = 0.465 NS	r = 0.422 NS		r = 0.130 NS	r = 0.075 NS
Taste preference	r = 0.526 $p<0.05$	r = 0.261 NS	r = 0.178 NS	r = 0.197 NS	r = 0.130 NS		r = 0.635 $p<0.05$
Texture preference	r = 0.431 $p<0.05$	r = 0.180 NS	r = 0.074 NS	r = 0.134 NS	r = 0.075 NS	r = 0.635 $p<0.05$	

NS = Non-significant

Correlations between taste responses to corn oil and preference for fat containing foods

Sweetness

No significant correlations were found between perceived sweetness of corn oil and hedonic rating for any of the fat-containing foods listed in the questionnaire.

Saltiness

Small, but statistically significant negative correlations were found between perceived saltiness of corn oil and preference for peanuts (r = -0.259, p<0.05), peanut butter (r = -0.229, p<0.05), yoghurt (r = -0.240, p<0.05) and dark chocolate (r = -0.241, p<0.05).

Sourness

Significant negative correlations were found between perceived sourness of corn oil and hedonic rating for marscarpone cheese (r = -0.395, p<0.05), peanuts (r = -0.253, p<0.05) and peanut butter (r = -0.262, p<0.05).

Bitterness

Statistically significant negative correlations were found between perceived bitterness of sunflower oil and liking for peanuts (r = -0.304, p<0.01) and peanut butter (r = -0.227, p<0.05).

Intensity

Perceived intensity of corn oil was significantly negatively correlated with preferences for cream cheese (r = -0.251, p<0.05), crème fraiche (r = -0.259, p<0.05), fried rice (r = - 0.225, p<0.05) and marscarpone cheese (r = -0.423, p<0.01).

Taste preference

Small but statistically significant positive correlations were found between taste preference for corn oil and hedonic ratings for brie (r = 0.298, p<0.05), butter (r = 0.239, p<0.05), margarine (r = 0.246, p<0.05) and stilton cheese (r = 0.39, p<0.01).

Texture preference

Significant negative correlations were found between preference for the texture of corn oil and liking for cream (r = -0.232, p<0.05) and pesto (r = -0.303, p<0.05). Significant positive correlations were found between preference for the texture of corn oil and hedonic rating for margarine (r = 0.336, p<0.01), buttered popcorn (r = 0.281, p<0.05) and fried breakfast food (r = 0.238, p<0.05).

Relationship between "fat taster status" and preference for fat-containing foods

On the basis of taste quality perceived most strongly in the oils, 24 (30%) individuals were classified as sweet tasters, 21 (26.3%) as salty tasters, 14 (17.4%) as sour tasters and 21 (26.3%) as bitter tasters.

Table 20 contains mean hedonic ratings for foods and standard deviations for each "fat taster" group:

Table 20: Mean hedonic ratings for fat-containing foods for group related to the predominant taste quality perceived in oil

		Predominant taste quality perceived in corn oil ("taster group")			
	Food	Sweet	Salty	Sour	Bitter
Mean	Avocado	37.88	40.20	43.00	38.50
±		33.93	35.59	31.79	28.94
Mean	Bacon	64.65	62.74	68.25	61.10
±		31.49	30.77	28.27	30.44
Mean	Beef	61.87	68.25	59.77	63.90
±		32.97	28.28	35.38	30.99
Mean	Burgers	42.57	52.00	41.92	61.33
±		24.69	28.88	22.90	27.03
Mean	Biscuits	80.54	71.10	54.21	76.40
±		17.17	26.51	28.16	23.39
Mean	Brie	57.18	47.59	52.67	54.12
±		33.41	35.97	21.58	38.10

		Predominant taste quality perceived in corn oil ("taster group")			
	Food	Sweet	Salty	Sour	Bitter
Mean	Butter	54.71	56.62	57.64	49.24
±		29.92	26.37	29.95	28.08
Mean	Cakes	76.38	74.81	71.43	72.10
±		21.14	20.32	15.39	22.95
Mean	Cheddar	84.42	61.81	74.50	70.62
±	cheese	12.29	30.39	18.22	32.17
Mean	Chicken	79.52	77.35	69.46	80.52
±		19.97	25.40	32.73	20.27
Mean	Chips	67.00	71.19	70.50	76.00
±		20.19	21.31	23.90	21.75
Mean	Coconut	44.75	53.33	45.57	47.55
±		27.82	35.52	32.60	30.12
Mean	Cream	55.29	59.97	52.43	52.43
±		26.44	30.57	27.88	35.42
Mean	Cream	51.58	40.40	49.15	52.67
±	cheese	31.58	31.92	28.84	31.17
Mean	Cream	57.46	48.50	49.38	52.15
±	crackers	21.46	19.86	24.28	31.18
Mean	Crème	47.63	37.18	36.30	40.60
±	fraiche	32.47	28.37	30.09	27.35
Mean	Crisps	72.79	73.85	65.29	63.67
±		19.61	18.78	26.20	29.65
Mean	Croissants	71.58	66.80	50.86	74.65
±		23.78	28.54	27.72	19.41
Mean	Curries	67.67	73.71	57.36	67.48
±		30.61	29.58	34.93	35.36
Mean	Custard	61.79	60.76	49.43	56.05
±		28.26	34.55	30.66	22.11
Mean	Dark	63.33	40.33	41.29	33.76
±	chocolate	29.41	38.21	34.66	33.98
Mean	Donuts	64.92	54.00	54.64	64.24
±		24.15	31.76	26.58	23.63
Mean	Duck	55.75	56.19	25.80	39.56
±		31.32	31.83	27.85	29.53
Mean	Eggs	68.08	58.86	69.00	62.95
±		17.87	23.87	19.28	23.89
Mean	Fish and	65.22	66.05	54.79	63.55
±	chips	22.93	24.51	36.14	29.89
Mean	Fried rice	56.87	66.05	54.79	63.55
±		28.66	24.51	36.14	29.89
Mean	Fried	58.26	62.05	56.07	57.33
±	breakfast	33.15	28.77	32.32	29.88
Mean	Fromage	44.05	51.50	33.58	47.89
±	frais	31.67	29.09	32.22	31.45
Mean	Ice cream	77.17	72.43	64.71	72.52
±		21.53	23.44	26.14	22.81

		Predominant taste quality perceived in corn oil ("taster group")			
	Food	Sweet	Salty	Sour	Bitter
Mean	Lamb	52.04	70.45	74.00	61.86
±		29.74	27.39	28.51	32.11
Mean	Margarine	52.26	45.71	61.50	44.33
±		18.76	23.43	31.44	20.84
Mean	Marscarpone	39.86	34.86	36.14	33.60
±	cheese	31.98	29.44	31.29	33.09
Mean	Mayonnaise	52.29	51.38	58.50	55.50
±		33.43	32.00	31.73	29.31
Mean	Milk	83.50	80.19	82.00	80.38
±	chocolate	17.03	19.63	18.30	24.17
Mean	Peanuts	58.61	61.00	60.50	48.00
±		27.10	29.00	32.60	30.88
Mean	Peanut butter	33.98	37.55	28.43	30.26
±		26.51	33.55	30.71	30.74
Mean	Pesto	43.29	49.92	52.00	47.93
±		35.31	27.69	29.24	34.99
Mean	Pizza	73.75	71.05	80.71	74.10
±		21.91	39.66	13.72	26.86
Mean	Popcorn	68.62	44.86	60.43	51.86
±		18.14	30.99	22.72	29.88
Mean	Pork	58.52	58.16	63.23	51.81
±		31.22	29.45	31.28	30.82
Mean	Roast dinner	71.63	75.75	79.77	79.00
±		29.69	20.91	23.30	28.89
Mean	Salad	50.38	49.71	58.21	57.86
±	dressing	30.46	33.63	29.13	31.14
Mean	Sausages	56.30	54.00	61.31	63.83
±		31.19	30.48	26.22	28.54
Mean	Savoury pies	44.17	51.85	61.31	53.86
±		30.18	24.41	26.22	27.48
Mean	Semi	61.70	55.38	68.43	62.81
±	skimmed milk	17.64	31.16	30.65	27.80
Mean	Skimmed	44.04	39.62	50.46	36.67
±	milk	32.38	35.12	37.74	28.07
Mean	Sour cream	35.10	24.58	20.20	33.75
±		32.17	27.91	27.52	32.01
Mean	Stilton	39.41	26.11	32.08	43.21
±		37.14	34.41	32.02	39.89
Mean	Sweet pies	65.71	63.14	57.33	65.19
±		25.32	29.53	28.87	23.61
Mean	Taramasalata	35.50	40.29	60.11	30.50
±		28.96	28.57	35.89	31.02
Mean	White	51.21	64.14	53.36	52.94
±	chocolate	34.00	29.55	34.29	29.24

	Food	Predominant taste quality perceived in corn oil ("taster group") Sweet	Salty	Sour	Bitter
Mean	Whole milk	51.48	53.14	35.85	34.24
±		32.55	27.32	34.77	33.38
Mean	Yoghurt	75.92	71.86	54.00	66.10
±		23.51	25.03	29.10	26.07

One-way ANOVAs were carried out and significant differences were found between "fat taster" groups for cheddar cheese ($F(3,76) = 3.186$, $p<0.05$) dark chocolate ($F(3,76) = 3.270$, $p<0.05$), duck ($F(3,76) = 3.007$, $p<0.05$) and buttered popcorn ($F(3,76) = 3.470$, $p<0.05$). However, in the case of both cheddar cheese and popcorn it should be noted that Levene's statistic indicated that the assumption of homogeneity of variance had been violated (cheddar cheese Levene's statistic (3,76) = 4.562, $p<0.01$, popcorn Levene's statistic (3,76) = 4.964, $p<0.01$).

Bonferroni's pairwise post-hoc analysis indicated that the significant main effect for dark chocolate can be attributed to significant differences between individuals who perceived the predominant taste quality in oil to be sweet and those who perceived it to be bitter. Means in *Table 20* indicate that those in the bitter taste group gave significantly lower hedonic ratings for dark chocolate than those in the sweet taste group.

When applied to duck, Bonferroni's post-hoc analysis indicated that, despite the significant main effect, no significant differences could be found for pairwise comparisons. Means in *Table 20* show that individuals in the sour taste group gave the lowest hedonic ratings for duck, whilst those in the sweet and salty groups expressed the greatest liking.

Due to the fact that equal variance could not be assumed in the cases of cheddar cheese and buttered popcorn, the Games-Howell post-hoc analysis was applied to both. Findings indicated that, for cheddar cheese the significant main effect was related to significant differences between the sweet and salty taste groups. Means, illustrated in *Table 20*, showed that sweet taste responders had given greater hedonic ratings for cheddar than salty respondents.

In the case of buttered popcorn, the Games-Howell test indicated that significant findings could also be attributed to differences between sweet and salty fat taste responders. Means indicate that those who perceived oil to be predominantly sweet had a significantly elevated preference for buttered popcorn when compared with those who perceived oil as predominantly salty.

Factor Analysis

Principal Components Analysis was applied to the foods listed on the food preference questionnaire, however despite small-moderate correlations between some food types, no meaningful solution of factor reduction could be reached.

Discussion

The findings of this study indicated that significant relationships were present between taste responses to corn oil and hedonics for a number of specific fat-containing foods. Significant negative correlations existed between perceived preferences for peanuts and peanut butter and ratings of saltiness, sourness and bitterness in corn oil. Peanut butter is characterised by a relatively salty flavour, whilst peanuts themselves are frequently consumed as a salted snack, therefore it is possible that enhanced sensitivity to saltiness in fat may be responsible for decreased preference for these foods. The link between enhanced perception of sourness and bitterness in oil and decreased hedonic ratings for peanuts and peanut butter may be a reflection of the high significant positive correlation both taste qualities share with perceived saltiness.

Significant negative correlations were also found between perceived saltiness of corn oil and liking for both yoghurt and dark chocolate. Both of these foods are characterised by sweet and sweet-bitter flavours respectively and this finding could be a reflection of those perceiving fat to be saltier preferring or consuming more savoury high-fat food. However it should be taken into account that no significant correlations were found with sweet high-fat foods such as ice-cream, cakes or biscuits. Finally, correlation analysis revealed a significant negative relationship between perceived sourness of corn oil and hedonic rating for marscarpone cheese. This soft, high-fat dessert cheese shares many of the taste characteristics of foods such as natural yoghurt and could be perceived as having a sour component to its overall favour when eaten unsweetened, thus making it less desirable to those individuals sensitive to the sour taste qualities of fat.

In terms of perceived intensity of the taste of corn oil, this was significantly negatively correlated with cream cheese, crème fraiche, fried rice and marscarpone cheese, all of which have high fat contents and contain fat as a prominent aspect of the food matrix. This was also the case for the foods that correlated positively with taste preference for corn oil (brie, stilton, margarine and butter) and with texture preference for corn oil (margarine, buttered popcorn, fried breakfast foods). This suggests that preferences for pure fats may be transferable to foods which contain high and obvious levels of fat, whilst high levels of perceived intensity in the taste of pure fats may lead to such foods being perceived as less pleasant. However, it should be taken into account that these correlations were relatively small, despite their significance and that a number of other foods which share similar properties, such as cream and fried breakfast food, did not elicit these responses.

Therefore, on the basis of these findings it would appear that experimental hypothesis 1, which stated that "*there will be a significant relationship between taste responses to fat and preferences for fat-containing foods*" can be upheld. However it must also be taken into account that this relationship is by no means clear or consistent and that further investigation is required. Whilst rational hypotheses can be proposed for a number of these findings, others such as the significant relationship between cream crackers and perceived intensity of oil, are more problematic to interpret. Equally, many of the results revealed for specific foods fail to replicate to other similar food types. This could suggest that previous published research indicating that preferences for basic sweet or salty solutions do not necessarily relate to liking for sweet or salty foods, may also be applicable to fat and fat-containing foods (Lucas and Bellisle 1987; Mattes 1985; Pangborn and Pecore 1982). The failure of Principal Components Analysis in reducing the foods into meaningful categories indicates that hedonic rating is not a reliable predictor of food type, or vice versa. However this also makes interpretation of the results somewhat more difficult.

Respondents were divided into taste responder categories according to the predominant taste quality they perceived as being present in corn oil. Significant differences were found between taste responder categories in preferences for dark chocolate, duck and buttered popcorn. Post-hoc analyses revealed that all of these significant main effects could be attributed to the fact that respondents who perceived oil to be predominantly sweet preferred each of these foods more than other taste responders. In the case of dark chocolate the significant difference was present between sweet and bitter taste respondents. Dark chocolate contains sugar, but is also characterised by bitter taste qualities. The enhanced preference of sweet taste responders could be related to them perceiving dark chocolate as sweeter or being more accepting of its bitterness than those who appear more sensitive to bitter taste qualities in pure fats. This is also supported by the fact that bitter taste respondents gave the lowest mean hedonic rating for dark chocolate.

For both buttered popcorn and duck, the significant differences were found between sweet and salty taste respondents. These foods both share a tendency towards greasy textural properties but fall into very different food groups and have very different flavours. The preference of sweet taste respondents for popcorn could reflect an enhanced liking or tendency to consume more sweet snacks than salty respondents. The preference for duck is less clear but it should be noted that it was not a commonly consumed food and many participants had never eaten it and were thus enable to rate their preference.

The above findings indicate that experimental hypothesis 2, which stated that "*there will be a significant relationship between predominant taste quality perceived in oils and preferences for fat-containing foods*" can be accepted. However, in interpreting these findings, it should be taken into account that the classification of taste-responders to oil is an arbitrary technique and therefore caution must be exercised when drawing conclusions. Equally, it is clear that, whilst significant differences were found, these were small in number, inconsistent across food groups and at times difficult to interpret. Therefore, despite the presence of significant differences it would seem that classification of individuals based upon the dominant taste quality perceived in fat may not be a particularly useful or valid predictor of food preferences.

The use of food preference questionnaires in this study as a means of determining hedonic responses to fat-containing foods appeared to produce a range of valid and meaningful responses. However it may have been useful to incorporate a number of real food samples into the study for respondents to taste in order to test whether these responses were replicated by the preference questionnaire. It should also be noted that the food preference questionnaire listed only fat-containing foods, as opposed to a range of different foods and nutrients. Therefore, as was found in Study 7's investigation of dietary consumption, more coherent and interpretable results may be found by examining preferences for a range of food and beverage types.

As was discussed in Chapter 7, many researchers view studies of food intake based upon surveys and self-reports with suspicion due to the high possibility for deceptive or inaccurate data (Mela 1995). The same criticism may be made of food preference questionnaires, particularly when they relate to fat-containing foods, as respondents may deliberately or inadvertently portray their preferences inaccurately due to a variety of factors, including health and dieting concerns. This study aimed only to focus upon food preferences, thus eliminating cognitions such as health and dieting concerns which come with actual food consumption. Research has indicated that liking for specific foods can be strongly linked to physiological, psychological, pharmacological and social factors (Mela 1995) and, realistically, even hypothetical preference ratings for foods an individual is not actually required to consume will still be influenced by such issues. However, in carrying out further research relating to food preferences and taste responses to fats, it may be of interest to compare hedonic ratings within the food preference questionnaire to responses given for actual food samples, as a means of testing reliability.

Overall Conclusion

The overall findings of this study indicated that a relationship does appear to exist between sensory responses to pure fats and actual preferences for fat-containing foods. However the extent to which taste responses to pure fats determine food preferences is more questionable, given that significant relationships were confined to specific food types, as opposed to overall groups. Results were, in some cases, problematic to interpret and no evidence was found to indicate that individuals who preferred particular taste sources of dietary fat, i.e. sweet, savoury, responded to pure fat accordingly. Based upon these findings it would also appear that preferences for pure processed oils demonstrate more interpretable and important relationships to food preferences than the actual taste characteristics of the oil. This may be due to the fact that the taste component of fat is easily incorporated into and disguised by the overall food matrix and properties and it is these which are the more important determinants of hedonic response to the food. Further research is clearly needed within this area but at present it would appear that taste responses to pure fats are only a small contributory factor in determining preferences for fat-containing foods.

Study 9

The relationship between self-reported dietary preferences and taste responses to fats

Introduction

The findings of Study 8 indicated that further research was required in an attempt to clarify the relationship between taste responses to fat and food preferences. This study focused upon preferences for fat-containing foods in an attempt to examine whether specific sources or types of dietary fat could be related to specific taste responses in pure processed oils. However it was concluded that, whilst a relationship did appear to exist, it was neither clear nor consistent and it was suggested that focusing upon fat-containing foods alone was insufficient in generating conclusions concerning taste responses to fat and food preferences. Therefore, the aim of this study was to build upon these findings by investigating the relationship between taste responses to pure processed oils and hedonic ratings for a wider selection of foods and beverages. This was in order to investigate whether, for example, individuals who reported preferring healthy foods such as green vegetables or salads exhibited different taste responses to pure processed oils than individuals who did not. Some indication of such a pattern was detected in Study 7's results relating to food intake, therefore it was considered of interest to examine whether these findings would be transferred to food preferences.

As was discussed in the previous study, concerns can be raised about how representative responses on a food preference questionnaire are of true sensory and hedonic responses to the actual foods. Previous research has suggested that responses to food names on a survey may reflect the general attitudes of the individual to the food in question, whereas ratings of samples in sensory tests are more likely to indicate liking specifically for taste characteristics (Cardello and Maller 1982). Therefore a further aim of this study was to establish whether hedonic ratings for a selection of foods and beverages listed on the food preference questionnaire could be significantly and reliably correlated to taste preferences for actual samples. This in turn would make an attempt to assess the validity of data generated from the food preference questionnaires.

In order to build upon the findings of the previous study, corn oil was once again used as a representative for pure processed oil but, olive oil was also selected as an additional stimulus. Study 3 indicated that these stimuli possessed fewer properties which could be attributed to their derivative ingredients as opposed to the fat component itself. The basic taste quality labels of sweetness, saltiness and sourness were used, whilst the label burnt replaced that of bitter, as Study 3 suggested that participants preferred this descriptor. In addition the term fatty was applied, which the findings of Study 3 seemed to suggest referred to a unique fatty taste or flavour.

The following hypothesis was generated for the purpose of this study:

Experimental Hypothesis 1: There will be a significant relationship between taste responses to fat and dietary preferences

Method

Design

This study employed a correlational design between two sets of variables; taste responses to pure processed oils and preferences for a range of foods and beverages.

Participants

50 participants were recruited for this study. They had all previously taken part in Study 7. All participants were females aged between 16 - 35 years old to control for gender and age as influencing factors. BMI ranged from 16.89 – 35.64, with a mean value of 24.54 (± 4.72). 9 (18%) participants had a BMI of <20 (categorised as below normal weight), 21 (42%) participants had a BMI within the range of 20 – 24.9 (normal weight), 13 (26%) had a BMI within the range of 25 – 29.9 (grade 1 obesity) and 7 (14%) had a BMI within the range of 30 – 39.9 (grade 2 obesity)

88% (n = 44) participants were self-reported non-smokers whilst 12% (n = 6) were smokers. 6 (12%) participants reported that they were vegetarians. No other specific dietary requirements were reported.

All participants were naïve as to the purpose of the study.

Materials

Stimuli

Sensory stimuli for this study consisted of a 10ml samples of corn oil (J. Sainsbury plc, London, UK) and olive oil (J. Sainsbury plc, London, UK). The fat was stored in a cool, dark environment, in order to minimse interaction with light and heat which may lead to the development of additional chemosensory properties (Mela and Sacchetti 1991) and were presented to participants at room temperature.

In addition to the fat stimuli, a selection of foods were also presented to participants. Food samples used were canned tuna in brine, medium cheddar cheese, coleslaw, crisp bread presented with cream cheese, lettuce and cucumber, sugared donuts, pure orange juice and skimmed milk.

Questionnaires

In order to rate the perceived taste qualities for the pure processed oil stimuli, participants completed response sheets containing 100mm line scales (anchored "not at all" and "extremely"). Taste qualities assessed in the oils were sweetness, saltiness, sourness, burnt and fatty. Participants were also required to record their preferences for the taste and texture of the oil stimuli, also using 100mm line scales.

Self-reported hedonic ratings for 86 foods and beverages was measured using 100mm line scales anchored "not at all" (0mm) and "extremely" (100mm) (see appendix 7). Hedonic ratings for the "real" food samples were also reported using the same 100mm line scales.

Procedure

Upon recruitment for this study, participants were requested not to smoke, clean their teeth, eat or drink anything except water for 2 hours prior to the study to minimise the risk that their taste perception of the fats would be contaminated. 10ml samples of corn oil and olive oil were presented individually in a random order in small opaque plastic cups. Participants were unaware as to the identity of the sample. Again a standard "sip-and spit" procedure was applied and, after completing the relevant sensory rating scales, participants were required to rinse three times with distilled water, spitting out each time, before repeating this procedure with the next sample. Participants were also required to take a 5-minute break between tasting and evaluating each fat sample. This was a recommended time needed to prevent the flavours of the sample being tasted being suppressed by those of the previous sample (Nguyen and Pokorny 1998).

Participants completed the food preference questionnaire containing 86 different foods and beverages. They were then presented with small quantities of the 10 "real" food samples in a random order and respondents were requested to taste and eat a mouthful of the food and rate their preference for it using 100mm line scales. Crisp bread, salad and cream cheese were presented together as these foods are not usually eaten alone and the context in which foods are normally consumed has been found by previous research to influence taste responses (Tuorila 1992). However participants were still required to rate their preferences for the three foods separately. Distilled water was provided for participants to rinse with after tasting each food sample.

Analysis

Pearson's correlation analysis was applied to examine the relationship between perceived taste characteristics and preferences for each pure processed oil and hedonic rating for individual foods and beverages. Principal components analysis was

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Results

Relationship between food preference questionnaire and hedonic rating for actual food samples

Significant positive correlations were revealed between preferences stated for each of the actual food and drink samples and hedonic ratings recorded for these items on the food preference questionnaire. Correlation values and significance levels can be seen in *Table 21*:

Table 21: The relationship between preferences for actual food and drink samples and hedonic ratings recorded on food preference questionnaire

Food or beverage	Correlations between actual samples and food preference questionnaire
Canned tuna in brine	$r = 0.996$, $p<0.001$
Cheddar cheese	$r = 0.993$, $p<0.001$
Coleslaw	$r = 0.992$, $p<0.001$
Cream cheese	$r = 0.992$, $p<0.001$
Crisp bread	$r = 0.985$, $p<0.001$
Donut	$r = 0.976$, $p<0.001$
Fruit juice	$r = 0.955$, $p<0.001$
Salad	$r = 0.950$, $p<0.001$
Skimmed milk	$r = 0.982$, $p<0.001$

These correlation values indicate a very close relationship between hedonic ratings given on the food preference questionnaire and those given for actual food and drink samples.

<u>Relationship between taste responses to pure processed oils and preferences for foods and beverages</u>

Sourness

Significant positive correlations were found between perceived sourness of olive oil and hedonic ratings for cream ($r = 0.29$, $p<0.05$), crackers ($r = 0.30$, $p<0.05$) and fromage frais ($r = 0.31$, $p<0.05$).

Significant negative correlations were found between perceived sourness of olive oil and preference for canned fish in brine ($r = -0.30$, $p<0.05$), chicken ($r = -0.34$, $p<0.05$), ham ($r = -0.32$, $p<0.05$), sausage ($r = -0.36$, $p<0.01$) and savoury pies ($r = -0.35$, $p<0.05$).

Significant positive correlations were revealed between perceived sourness of corn oil and preference for brie ($r = 0.30$, $p<0.05$), crackers ($r = 0.44$, $p<0.005$), crème fraiche ($r = 0.30$, $p<0.05$), crisp bread ($r = 0.52$, $p<0.001$), reduced-sugar soft drinks ($r = 0.36$, $p<0.05$), full-fat mayonnaise ($r = 0.29$, $p<0.05$), pesto ($r = 0.29$, $p<0.05$) and skimmed milk ($r = 0.34$, $p<0.05$).

Significant negative correlations were revealed between rated sourness of corn oil and hedonic ratings for canned fish in brine ($r = -0.37$, $p<0.01$), chicken ($r = -0.46$, $p<0.005$), fried breakfasts ($r = -0.28$, $p<0.05$), ham ($r = -0.34$, $p<0.05$), lamb ($r = -0.31$, $p<0.05$), roast dinners ($r = -0.28$, $p<0.05$) and savoury pies ($r = -0.30$, $p<0.05$).

Burntness

Significant positive correlations were found between perceived burnt taste quality in olive oil and preference for crackers ($r = 0.44$, $p<0.05$), fromage frais ($r = 0.31$, $p<0.05$) and cream ($r = 0.29$, $p<0.05$).

Significant negative correlations were revealed between perception of burntness in olive oil and hedonic ratings for canned fish in brine ($r = -0.30$, $p<0.05$), chicken ($r = -0.34$, $p<0.05$), ham ($r = -0.32$, $p<0.05$), sausages ($r = -0.36$, $p<0.05$) and savoury pies ($r = -0.35$, $p<0.05$).

Significant positive correlations were found between perceived burnt taste characteristics in corn oil and preference ratings for crackers ($r = 0.43$, $p<0.005$), crisp bread ($r = 0.51$, $p<0.001$), reduced-sugar soft drinks ($r = 0.35$, $p<0.05$) and skimmed milk ($r = 0.35$, $p<0.05$).

Significant negative correlations were revealed between perceived burntness of corn oil and reported liking for canned fish in brine ($r = -0.36$, $p<0.05$), chicken ($r = -0.45$, $p<0.005$), ham ($r = -0.35$, $p<0.05$), lamb ($r = -0.30$, $p<0.05$), sausages ($r = -0.30$, $p<0.05$) and savoury pies ($r = -0.35$, $p<0.05$).

Saltiness

Significant positive correlations were found between perceived saltiness of olive oil and liking for crème fraiche ($r = 0.31$, $p<0.05$), reduced-sugar soft drinks ($r = 0.31$, $p<0.05$), salad dressing ($r = 0.28$, $p<0.05$), salad cream ($r = 0.40$, $p<0.005$) and vegetarian meals ($r = 0.43$, $p<0.005$).

Significant negative correlations were found between rated saltiness of olive oil and preferences for burgers (r = -0.35, p<0.05), eggs (r = -0.31, p<0.05) and pesto (r = 0.30, p<0.05).

Significant positive correlations were found between perceived saltiness of corn oil and preferences for brie (r = 0.44, p<0.005), chilli (r = 0.28, p<0.05), pesto (r = 0.30, p<0.05) and salad cream (r = 0.29, p<0.05).

Significant negative correlations were revealed between perceived saltiness of corn oil and hedonic rating for burgers (r = -0.42, p<0.005), eggs (r = -0.29, p<0.05), margarine (r = 0.34, p<0.05) and salad (r = 0.33, p<0.05).

Sweetness

No significant positive correlations were found between perceived sweetness of olive oil and preferences for any food or beverage type.

Significant negative correlations were revealed between olive oil and liking for boiled potatoes (r = -0.38, p<0.01), cakes and pastries (r = -0.32, p<0.05), canned fish in brine (r = -0.35, p<0.05), cream (r = 0.37, p<0.01), eggs (r = -0.31, p<0.05), fish and chips (r = -0.36, p<0.05), ham (r = -0.31, p<0.05), jam (r = -0.30, p<0.05), pasta in cream-based sauce (r = -0.32, p<0.05), salad cream (r = -0.30, p<0.05), sausages (r = -0.37, p<0.05), stilton cheese (r = -0.39, p<0.05) and whole milk (r = -0.29, p<0.05).

Significant positive correlations were found between rated sweetness of corn oil and preference for chips ($r = 0.29$, $p<0.05$), reduced-sugar soft drinks ($r = 0.35$, $p<0.05$) and donuts ($r = 0.41$, $p<0.005$).

No significant negative correlations were revealed between perceived sweetness of corn oil and hedonic ratings for any specific food or beverage.

Fattiness

Significant positive correlations were revealed between perception of a fatty flavour in olive oil and hedonic ratings for alcohol ($r = 0.38$, $p<0.01$), brie ($r = 0.29$, $p<0.05$), cheddar cheese ($r = 0.33$, $p<0.05$) and salad ($r = 0.29$, $p<0.05$).

Significant negative correlations were found between perceived fattiness in olive oil and liking for biscuits ($r = -0.33$, $p<0.05$), cakes and pastries ($r = -0.30$, $p<0.05$), chilli ($r = -0.30$, $p<0.05$), coffee ($r = -0.41$, $p<0.005$), curries ($r = -0.31$, $p<0.005$), fruit juice ($r = -0.30$, $p<0.05$), garlic ($r = -0.39$, $p<0.01$), ice cream ($r = -0.34$, $p<0.05$) and yoghurt ($r = 0.29$, $p<0.05$).

Significant positive correlations were revealed between perceived fattiness in corn oil and preferences for alcohol ($r = 0.47$, $p<0.05$), baked potatoes ($r = 0.37$, $p<0.01$), brie ($r = 0.34$, $p<0.05$), cheddar cheese ($r = 0.39$, $p<0.01$), chips ($r = 0.29$, $p<0.05$), crisps ($r = 0.36$, $p<0.05$), sausages ($r = 0.31$, $p<0.05$) and semi-skimmed milk ($r = 0.31$, $p<0.05$).

Significant negative correlations were found between perception of a fatty taste in corn oil and liking for biscuits ($r = -0.33$, $p<0.05$), coffee ($r = -0.31$, $p<0.05$), fruit juice ($r = -0.28$, $p<0.05$) and garlic ($r = 0.39$, $p<0.01$).

Taste Preference

Significant positive correlations were revealed between reported preference for olive oil and liking for salad dressing ($r = 0.28$, $p<0.05$) and skimmed milk ($r = 0.29$, $p<0.05$).

Significant negative correlations were found between liking for the taste of olive oil and preference for biscuits ($r = -0.30$, $p<0.05$), chicken ($r = -0.33$, $p<0.05$), hot chocolate ($r = -0.49$, $p<0.001$) and lamb ($r = -0.28$, $p<0.05$).

Significant positive correlations were revealed between hedonic rating for the taste of corn oil and preferences for chilli ($r = 0.36$, $p<0.01$), coffee ($r = 0.43$, $p<0.005$), garlic ($r = 0.38$, $p<0.01$), ice cream ($r = 0.34$, $p<0.05$), pork ($r = 0.40$, $p<0.005$) and stilton cheese ($r = 0.42$, $p<0.005$).

No significant negative correlations were found between taste preferences for corn oil and liking for any specific food or beverage.

Discussion

The results of this study revealed that a wide range of varying food and beverage types were significantly associated with taste responses and preferences for pure processed oils. These included fish, meats, cheeses, cream, bread and crackers, milk, chocolate, desserts, vegetables and salad, pasta and sauces, salad dressings and mayonnaise, curries, chilli, garlic, fruit juice, coffee, alcohol and soft drinks. More foods tended to be associated with the sweetness of olive oil than corn oil, possibly due to the fact that, as indicated by Study 5, olive oil was slightly more associated with sweeter taste qualities than corn oil. Overall, however, preference for the majority of foods showed a consistent relationship with taste qualities for both olive oil and corn oil. To a certain extent, detectible patterns could also be noted in the types of foods whose preference ratings correlated with taste responses to the oils.

Some indication was found that foods which may be considered healthier or lower in fat were positively correlated with perceived sourness, burntness and saltiness of both oils, suggesting that the more intensely these taste characteristics were perceived, the greater the preference for these foods, Such foods included crackers, crisp bread, reduced-sugar "diet" drinks, skimmed milk, salad, fromage frais and vegetarian meals. By contrast, a number of foods considered less healthy or higher in fat, such as meats, burgers and sausages and pies, were negatively correlated with perceived sourness, burntness, saltiness and sweetness in the oils, indicating that the greater the perception of these taste qualities the less these foods were liked. However, these findings were not consistent across all foods. A number of higher fat, less healthy foods, such as full-fat mayonnaise, salad cream and cheese were correlated positively with the above taste characteristics. The preference for salad creams and mayonnaise could be a reflection of elevated preferences for salads. Nevertheless these foods do not comply with the pattern of preferences for healthier foods relating to perception of increased intensity of sourness, burntness, saltiness and sweetness in oils.

In terms of perceived sweetness, some indication was found that sweet foods, such as jam, cakes and pastries, were less preferred by individuals perceiving olive oil as sweeter. This could be attributed to the possibility that respondents who were more sensitive to sweetness in fats are more sensitive to this taste quality overall and therefore very sweet or sucrose-high foods, i.e. jam, are perceived as tasting overtly sweet and are thus less pleasant. However the validity of this hypothesis is placed into question by the failure to find comparable results in other sweet food listed on the questionnaire, such as honey, ice cream and chocolate.

As with Study 7's findings relating to dietary intake, the fatty taste characteristic correlated significantly to a different selection of foods and beverages than the other four taste qualities. Also comparable with the findings relating to dietary intake, were the negative correlations between perceived fattiness and fat-containing or sharp tasting foods such as ice cream, yoghurt, chilli, garlic, curries, coffee and fruit juice, all of which can be associated negatively with sensitivity to PROP. Therefore these findings are a possible reflection of genetically derived taste preferences. Equally, however, a number of other foods which could have been associated with PROP-sensitive aversion given their sharp or strong flavours (Forrai and Bankovi 1984; Tepper and Nurse 1997), such as alcohol and cheeses, were actually found to be positively correlated with perceived fattiness in pure processed oils. This reinforces the view that other factors may assert an overriding influence upon food preferences, i.e. liking for alcoholic drinks may be related to their effect and social contexts rather than the actual taste qualities of alcohol (Rogers and Richardson 1993).

Overall, these findings suggest that taste responses to pure processed oils do appear to be related to general dietary preferences. As in Study 7, Principal Components Analysis failed to reduce the foods into meaningful categories, again suggesting that individuals food preferences are not necessarily transferable across food groups. However examination of the results show some detectible patterns in the foods which correlate in a given way to the perceived taste qualities in the fat stimuli and, whilst some of these may be difficult to interpret, logical hypotheses can be provided for the majority. Thus, on the basis of these findings, experimental hypothesis 1, which stated, "*there will be a significant relationship between taste responses to fat and dietary preferences*" can be accepted.

It is of interest to note that, despite the fact that this study aimed to focus upon preference for a wide range of food types, as opposed to fat-containing foods alone, more significant relationships were found between taste responses to fats and hedonic ratings for fat-containing foods than were revealed in the previous study which focused upon fat-containing foods alone. This phenomenon was also observed in Chapter 7's studies of food intake and was partially attributed to possible increase in underreporting bias in response to a questionnaire containing only unhealthy foods (Macdiarmid and Blundell 1998; Goris, Meijer and Westerterp 2001; Vuckovic et al 2000). Previous published research has revealed that the presence of a "full-fat" label on foods such as yoghurt or cheese resulted in lower hedonic ratings than a "low-fat" label, regardless of actual fat content (Wardle and Solomons 1994). The fact that the food preference questionnaire in Study 8 obviously contained only foods with medium- to high fat contents may have had a similar effect to this in making respondents more aware of the presence of fat in the foods and thus altering their hedonic ratings.

Hedonic response to food and beverages is a complex issue which is likely to be influenced by multiple different factors. From the findings of this study it would appear that, whilst there is no clear and definite relationship between preference for fat-containing foods and taste responses to pure fat, the latter can be related to some degree to overall dietary preferences. The results of this study indicated that a strongly significant linear relationship existed between liking for specific foods and beverages as indicated using a food preference questionnaire and hedonic ratings given for actual food and drink samples. This suggests that the questionnaires, used both within this study and Study 8, provide a reliable and valid measure of dietary preferences. Therefore, failures to find consistent or apparently logical correlations are unlikely to be attributed to unreliable portrayal of food preferences. However it needs to be taken into account that neither food preference questionnaires, nor the use of actual food samples totally overcome the issues of attitudes, beliefs and concerns which may all influence or even override sensory responses to the food samples (Tuorila 1992). Equally, despite the fact that attempts were made to serve food samples in a way in which they would normally be consumed, i.e. serving crisp bread with cream cheese and salad, such a lab-based study still removes the usual contexts in which foods are eaten and this in itself may effect hedonic responses.

Overall, the findings of this study are indicative of an existing relationship between dietary preferences and taste responses to pure processed oils. The fact that this relationship cannot be categorised in a totally clear and consistent manner should be less surprising when it is considered that even foods within common categories or groups vary markedly in their taste characteristics and properties. Equally, the fact that preferences for foods and beverages are so complex and prone to the influence of numerous cognitive and external factors means that it is all but impossible to remove these and examine only the relationship between food preferences and sensory responses to fats.

Chapter 9

Discussion and Conclusions

How do individuals perceive dietary fat?

The results revealed within these studies are suggestive of a taste component existing within dietary fats. The studies carried out consistently indicated that, to a varying extent, individuals were able to detect the primary taste qualities of sweet, salty, sour and bitter within pure processed oils. Equally, Study 3 illustrated that respondents were also able to ascribe their own, individually generated taste descriptors to pure processed oils, thus suggesting that the taste component of fats was not just a response to forced choice taste categories. These findings suggest that Gilbertson et al's (1997; 1998) results indicating that rat taste receptor cells responded to fat may also be applicable to humans. The results also explicitly test, support and build upon the hypothesis drawn from Schiffman et al's (1992) study, which suggested some form of taste component to human detection of dietary fat, whilst refuting the conventional wisdom that fat is tasteless and detected by textural cues alone (Mela 1990).

What could not be established by this work was the consistent association of any specific taste qualities with fats. This could give support to Mela's (1990) assertion that no specific taste qualities could be associated with dietary fat. However, on the basis of the results of Studies 2 and 3, it appears more likely that this is reflective of individual differences which appear to exist in the types of taste qualities people ascribe to dietary fats and, more clearly, the intensity at which they perceive them. This in turn supports and extends the anecdotal evidence of Gilbertson (no published data. *The Guardian*

(London Newspapers) 3rd March 1998, pp16), which suggested that humans are able to describe the taste of fat, but with large individual differences, with some claiming it has a sweet taste, whilst others report sour or salty flavours. This could be seen, not just in the individual variation in taste scores illustrated by multidimensional scaling in Study 2, but also in the differences between individual responses when asked to state the predominant taste quality they perceived in pure processed oils in Studies 6 and 8.

In terms of the taste qualities ascribed to pure fats, Study 3 indicated that pure processed oils did posses their own unique taste qualities depending on the derivative ingredients of the oil. Therefore, when interpreting the findings of this research it needs to be taken into account that individuals may have been responding in part to taste qualities within the oil stimuli not related to the fat itself. Nevertheless Study 3 also indicated that many respondents detected a taste quality they described using terms such as "fatty," "cooked" and "fried" which would appear to be indicative of a unique fatty flavour present in pure fats. This could be viewed as supported by previous published research, which indicated rat's ability to reliably distinguish between and show a consistent preference for nutritive (i.e. corn oil), as opposed to non-nutritive (i.e. Vaseline, mineral oil) oil samples (Smith and Greenberg 1991), despite their almost similar textural cues. This in turn also refutes Mela's (1990) assertion that fat is tasteless. Studies 7 and 9, which included the taste term "fatty" as a potential descriptor for pure processed oils, also revealed that respondent's ratings for the term were relatively consistent across different oil stimuli. This suggested that they were responding to the pure fat itself as opposed to derivative ingredients of particular oils. Equally, multidimensional scaling solutions in Study 2 demonstrated the close proximity of different pure processed oil samples within the perceptual space of the map, suggesting any variation due to specific derivatives of oils may be less important than their similarities as a result of being pure fats.

Gilbertson et al's (1998) work had suggested that perceived intensity of the effects of fat on taste receptor cells of rats was inversely related to preferences for it. Evidence for this mechanism within human respondents has not been consistently revealed by studies within this research. Some indication of this phenomenon was illustrated in the multidimensional scaling solution of Study 2, but the relationship was not strong enough to be statistically significant in aggregated analyses. Other evidence can also be found in the studies relating to age (Study 2), and sensitivity to 6-*n*-propythiouracil (PROP) (Studies 4 and 5), that individuals who reported lower perceived intensity in the tastes of pure processed fats gave higher hedonic ratings. However when the influence of such additional factors was not taken into account, the relationship between intensity and preferences reported by Gilbertson et al (1998) was not found. This could be attributed to the fact that rats may be more likely than humans to be led purely by sensory factors when selecting what to consume and that their sensory responses are unlikely to be influenced by cognitive and external factors in the same way as humans. Equally, the physiological methodology used by Gilbertson et al (1998) is very different to the human psychophysical and sensory research methods used within these studies.

As has been previously discussed, sources of dietary fat are vast and diverse and fat itself is very rarely consumed in its simple form, and is usually acceptable only as a component of a complex food system (Mela 1990), which, in turn, changes and disguises the properties of the fat. Therefore, providing the stimuli to appropriately represent dietary fat within this research was one of the more problematic aspects of the design. The use of pure processed oils was deemed appropriate due to the fact that it has the advantage of being a simple and basic form of fat which is actually consumed within everyday diets. Nevertheless, such fats are rarely consumed alone and carry with them the added issue of additional chemosensory properties which, whilst this was addressed and overcome, provided extra complications.

It is clear from the findings of this research that taste qualities elicited by dietary fats are both subtle and complex. Therefore, it could be questioned how successful relatively untrained assessors could be in adequately describing the taste characteristics they perceived and that this, in part may have contributed to the individual variation found. However the techniques used within these studies were based mainly on those applied successfully in previous published works (i.e. Drewnowski and Greenwood 1983) and the inclusion of replicated samples in Study 3 indicated the consistency and validity of participant responses. The aim of this research was to address possible taste responses to fat within the general population and this could not have been achieved by using assessors formally trained in sensory techniques.

Individual Differences in Taste Responses to Fats

As stated above, the findings of these studies suggested participants were able to detect a taste component in fats. However no specific, consistent taste responses to pure processed oils were revealed in aggregated analysis and multidimensional techniques suggested this may be reflective of individual differences in taste responses to fats. Factors which were addressed within this research as potential contributory factors to individual variation included gender, age, sensitivity to PROP, dietary preferences, dietary intake, body mass, dieting behaviours and restraint status.

The demographic factors of age and gender were both found to have a small but relatively limited effect upon individual's taste responses to pure fats. The multidimensional scaling solution indicated that a greater proportion of males perceived pure processed oils as tasting sweeter than females. This difference was not robust enough to be demonstrated within aggregated analysis, where no gender-related distinctions in perceived taste qualities were revealed. However, in contrast to previous published findings (Pangborn and Sacchetti 1984; Drewnowski et al 1989; Mela and Sacchetti 1991), it was revealed that males gave greater hedonic ratings than females, for both the taste and texture of pure processed oils, although this pattern was not significant across all fat samples. Whilst there appears to be a sensory component to these differences, the influence of attitudes and social differences between males and females must also be taken into account. Published research has suggested that females tend to hold more negative attitudes towards dietary fat and fat-containing foods (Shepherd and Stockley 1987), and this may have been a contributory factor in creating this pattern of results. Therefore, overall, whilst gender-related differences were revealed in taste responses to fats, they did not appear to contribute to individual variation in perceived taste qualities and their influence upon taste preferences cannot be purely attributed to sensory variation.

Age revealed a relatively similar pattern of results to gender in that it was not found to have a significant effect upon the taste qualities ascribed to pure fats. However the results did indicate that older participants preferred the taste and textural properties of the pure processed oils more than younger respondents, although this was again not significant across all fat samples. A multidimensional scaling solution illustrated that older participants tended to perceive pure fats as tasting less intense, suggesting that Gilbertson et al's (1998) findings relating to rats and the negative correlation between intensity and hedonics may be applicable. However, it should be taken into account that no significant relationship between age and intensity was revealed by aggregated analysis. However, as was discussed within Study 2, the fact the findings do offer support to previous research suggesting that older adults may have a reduced ability to detect fat accurately and increased discrimination thresholds for fat (Mela, Langley and Martin 1994; Schiffman et al 1992). This would suggest that any differences to occur in taste perceptions of fats are reflective of and reliant upon age-related reductions in taste acuity and, without these, age may be less of a major contributory factor towards individual differences in sensory responses to fats.

As with age and gender, no distinctions were found between the types of taste qualities perceived in relation to sensitivity to 6-*n*-propylthiouracil (PROP). However differences were revealed in the intensity of these taste characteristics, with supertasters tending to ascribe ratings of greatest intensity. However, whilst intensity for taste qualities increased with PROP sensitivity for corn oil, findings were less consistent for walnut oil, with medium- and non-tasters ratings indicating the reverse of this pattern at times. This may be attributed to more intense additional chemosensory properties in walnut oil altering the responses of the less sensitive medium and non-taster respondents. Preference for pure fats were found to be inversely related to PROP sensitivity This supports not only the findings of previous published research relating to PROP and fat preferences (i.e. Tepper and Ullrich 2002), but also provides further indication that Gilbertson et al's (1998) hypothesis drawn from rat studies may be applicable to humans. Therefore, whilst genetically derived taste sensitivities do not appear to influence the types of taste qualities perceived in pure fats, they do seem to exert an influence upon the intensity with which these are perceived and overall preferences.

On the basis of these findings relating to PROP sensitivity and taste responses to pure fats, this research also focused upon examining whether these results were transferable to or exerted any influence upon taste responses to fat-containing foods. However, the findings indicated that PROP sensitivity did not appear to be related to the types of dietary fat sources an individual reported preferring or to overall hedonic ratings for fat-containing foods. This is in contrast to some previous published research suggesting that PROP taster status influences preferences for fat-containing foods (Forrai and Bankovi 1984; Duffy and Bartoshuk 2000). This may suggest that, whilst genetically derived taste sensitivities may influence taste responses to basic fats, when dietary fat is actually integrated into a consumable food source, it no longer appears to be an influencing factor.

Tepper and Ullrich (2002) have suggested that attitudinal factors such as restraint may be pertinent in disguising the influence of genetic taste sensitivity. The issues of restraint, dieting behaviours, dietary intakes and preferences were also examined within this research as potential contributors to individual variation in taste responses to fat. Initial investigation of purely fat-containing foods indicated that preference for a number of specific food did appear to be related to both taste qualities perceived in pure fats and preferences. These included foods such as peanut butter, cream crackers, yoghurt, dark chocolate, cheeses, crème fraiche, fried rice, fried breakfast foods and spreads. These results supported and extended the findings of previous published research, which had indicated a relationship between preferences for fat-containing stimuli and dietary intake or preferences (Mela 1989 unpublished; Mattes 1993; Fisher and Birch 1995). However correlations tended to be small, isolated to specific taste responses and other foods sharing similar properties did not tend to elicit the same responses suggesting that these findings were food-specific. A similar pattern of findings was also observed in the relationship between taste responses to fats and intake of fat-containing foods. Consumption of foods such as biscuits, dark chocolate, mayonnaise, taramasalata, cheeses, fish and chips, cream crackers, bacon and duck were revealed to be significantly related to specific taste qualities detected in pure processed oils. However, as with food preferences, the extent to which these findings can be generalised is questionable.

A comparable pattern of results between preferences and intake and their relationship with taste responses to pure fats was also revealed in Studies 7 and 9, which surveyed a wider range of nutrients, foods and beverages than Studies 6 and 8 which had examine fat-containing foods alone. For both preferences and intake significant, relationships were found between specific taste responses to fat and a range of foods including cheese, meats, chocolate and desserts, salad cream and dressings, fruit, salad and vegetables, fish, curries, chilli, pasta, bread and crackers, coffee, alcohol and soft drinks. It also appeared that consumption of and, to a slightly lesser degree preferences for, meats, meat products and foods considered less healthy were associated with reduced perceived intensity of the taste qualities sour, burnt, sweet, and salty which were used to rate the pure processed oils. Equally consumption of and preferences for a number of healthier items, such as crisp bread, salad and reduced-sugar soft drinks was significantly associated with increased intensity of these taste characteristics. This may suggest that increased perceived intensity of the taste qualities of fat may be either a cause of effect of preferring or consuming a healthier diet. These findings were also replicated when explicitly examining the relationship between selecting a lower-fat diet, using the Food Habits Questionnaire (Kristal, Shattuck and Henry 1990), and taste responses to fats. Overall, it would appear that, whilst the findings were somewhat food specific in some cases, they nevertheless provided evidence that dietary preferences and consumption may be related to individual differences in taste responses to dietary fat. However what is less clear from this research is whether variation in taste responses to fat is a cause or an effect of differences in dietary intake and hedonics. It should also be taken into account that, when considering the findings relating to dietary preferences and intake, no allowance was made for the fact that a small number of participants were self-reported vegetarians. Due to the fact that there were only a small proportion of the total respondents, the effects of vegetarianism could not be incorporated into the statistical analyses. However it would've been an influencing variable upon both liking and consumption of meat products.

As an additional point, an inverse relationship also appeared to exist between perception of fattiness in pure oils and both preferences for and consumption of a number of foods which have been implicated as being aversive to PROP sensitive individuals by previous published studies (Forrai and Bankovi 1984; Tepper and Nurse 1997). Given that sensitivity to PROP is also associated with increased sensitivity to fat in some previous published research (Tepper and Ullrich 2002), this result should not be surprising. However no significant relationships were revealed in Studies 4 or 5, which explicitly examined PROP sensitivity and preferences for fat-containing foods. This may be related to the methodology used for determining PROP taster status but, given that significant relationships were found with taste responses to pure fats using this method and that it had also been applied successfully in previous published works (i.e. Intranuovo and Powers 1998), this seems unlikely. A more tenable explanation for this discrepancy is that the potentially negative health and dieting issues raised by the food preference questionnaire used in Study 5 which listed only fat-containing foods, influenced respondents ratings so that these were not being based purely on sensory responses. Assessments of dietary intake methods have indicated that food items which carry negative health associations (i.e. fat-containing foods), are more likely to be under-reported in intake or preference than those with a positive health associations (i.e. fruit and vegetables) (Macdiarmid and Blundell 1998). This hypothesis is also supported by the fact that the food preference and frequency questionnaires used in Studies 7 and 9, which contained a range of nutrients and food types, elicited more correlations between taste responses to fats and intake or hedonics for fat-containing foods, than those in Studies 6 and 8, which listed fat-containing foods alone. This would suggest that respondents were more willing to admit to eating or liking these items when they were integrated with other, healthier foods and beverages.

Therefore, in considering the above findings relating to dietary preferences and consumption, the influence of diet-conscious cognitions, in addition to sensory factors, must not be forgotten. Thus, dieting behaviours and restraint were also examined as contributory factors to individual variation in sensory responses to fats. Study 6 indicated that Body Mass Index (BMI), whether an individual was dieting at the time of the study and their estimated dieting frequency and success were all unrelated to the taste qualities they perceived in pure fats. An inverse significant relationship was found between success in maintaining target weight after dieting and preference for the texture of pure processed oils. However, this gave no evidence for a relationship with the taste component of fat. Habitual restraint was addressed as an extension to these findings in Study 7. The results relating to this revealed that an inverse relationship existed between restraint and perceived fattiness of pure processed oils, whilst more restrained individuals also appeared to perceive pure fats as tasting sweeter, and reported elevated hedonic ratings for them. This would suggest that, whilst actual conscious state of dieting may not affect taste responses to fats, habitual restraint status may be a cause of individual variation. However, as has been discussed previously, sensory responses do not necessarily determine actual intake behaviour, particularly in restrained individuals (Lahteenmaki and Tuorila 1995). Therefore, these findings, which appear to provide a positive taste profile in restrained individuals for dietary fat, are unlikely to transfer to actual dietary fat consumption.

In conclusion, it would appear that, to varying extents gender, age, sensitivity to PROP, dietary preferences, intake and restraint all act as influencing factors upon individual variation in taste responses to fat. However, in general, these differences appear to exist in the form of differing levels of intensity with which the taste qualities detected in fat are perceived, as opposed to the perception of specific taste characteristics being associated with given traits or states. Equally, each of these factors appears to exert only limited influence upon sensory responses, with the potential for having this relationship cancelled out by additional influences and, as been clearly illustrated, taste responses to pure fats do not necessarily relate clearly to overall dietary fat intakes. Therefore, the potential for using taste responses to fats as a marker for issues such as over-consumption, obesity or eating disorders is at present very limited. Much more research is required to further establish and clarify the taste component of fat. Gilbertson et al (1997) have suggested that fat may actually stimulate all the major taste receptor cells and, whilst these studies have indicated strongly the presence of a specific fatty taste quality, this in itself may create sensory confusion resulting in some individual variation. Overall, taking into account the complex nature of this issue, much more research is needed to build upon this work and further clarify the nature and causes of individual differences in the sensory perception of fats.

Suggestions for future research

The findings of this research hold a number of promising suggestions for further research. In relation to furthering understanding of human sensory perception of dietary fat, much work needs to be carried out in order to demonstrate that these findings suggesting a taste component to fat can be reliably replicated. As previously discussed, the use of fat stimuli within this research was confined, in general to pure processed oils. Therefore it would be of interest to examine whether a similar pattern of findings could be demonstrated using specially prepared deodorized fat samples with no additional ingredients. If, as this work suggests, dietary fat carries with it a taste component, it is vital that the nature of this be more fully understood as it may have strong implications for health education and policy which has until now assumed that taste is not a relevant issue. The development of fat substitutes and low-fat food products that are considered as palatable as their full-fat counterparts also presents an ongoing challenge to the food industry (Aaron, Mela and Evans 1994). The notion that fat has a detectable taste profile may have important implications for future improvement and development of these.

The findings of this research also provide suggestions for further valuable work in areas beyond the focus of taste perception alone. Health education relating to dietary content tends to address the general population as a homogenous group. However the apparent presence of individual differences in a number of areas indicated by this research suggests that it may be useful to review such a policy. Both Chapters 7 and 8 indicate that a relationship may exist between preferences for and consumption of particular food groups and taste responses to fat. Further work within this area to provide clarification of the characteristics of different types of responders may help to target health and dietary education more effectively. Equally, this research has also provided important clues on factors such as dietary history and individual methods of dieting and fat restriction that would merit further investigation. The fact that markers for dieting success, such as restraint and use of fat reduction strategies has been shown to relate to taste responses to pure fats suggests that it may be of interest and value to extend this to consider whether these factors also relate to the precise types of foods such individuals prefer and consume. Once again this also holds promise for health education and policy.

It has been suggested that different types of dieting strategies are associated with different behavioural outcomes (Smith et al 1999), which could include both intake of and taste responses to dietary fats. When considering the relationship between dietary restraint and taste responses to fat, this research focused solely upon successfully dieting as identified by the Dutch Eating Behaviors Questionnaire (DEBQ) (Van Strien, Frijters, Bergers and Defares 1986). Therefore it may be of interest to consider whether measures of different types of restraint or dieting behaviour may reveal either a similar or different pattern of findings. One such possibility could be the use of the Restraint Scale, which was hypothesized to identify unsuccessful dieters (Herman and Polivy 1980; Heatherton et al 1988).

Equally, work carried out by Westenhoefer (1991) suggests that dietary restraint, as measured by the Three Factor Eating Questionnaire (TFEQ) (Stunkard and Messick 1985) can and should be differentiated into two distinct types; Rigid Control and Flexible

Control. The Rigid Control scale was composed of items describing calorie counting and strict dieting regimes, whilst the Flexible Control scale included items relating to being conscious of food intake and eating less after breaking a diet. Subsequent research has suggested that these varying types of restraint can be differentially associated with factors such as BMI, weight instability, symptoms of anorexia nervosa and bulimia nervosa and tendency to engage in overeating or binge eating behaviours (Shearin et al 1994; Westenhoefer et al 1994; Westenhoefer, Stunkard and Pudel 1999; Smith et al 1999). Therefore it would seem feasible to hypothesise that these different restraint types may also be associated with varying patterns of dietary fat intake and potentially different taste responses to fat. This would certainly merit investigation as the ability to use distinct dieting or eating styles as a marker for dietary fat intake may prove to be a useful target for health education or policy.

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Appendix 1

Response sheet for recording perception of basic taste qualities in fats and oils

Please rate the sample for the following taste attributes. For each taste quality mark the line at the point you think best describes the taste. There is no right or wrong answer so please be completely honest.

Sweetness:

Extremely sweet — Not at all sweet

Salty:

Extremely salty — Not at all salty

Sour:

Extremely Sour — Not at all sour

Bitter:

Extremely bitter — Not at all bitter

Please rate how strong you feel the overall taste and flavour of the sample is:

Strongest imaginable — Barely detectable

Please indicate how much you like the taste of the sample:

Extremely — Not at all

Please indicate how much you like the texture of the sample:

Extremely — Not at all

Appendix 2

Taste Profiling – Training Example

- When generating descriptions of the taste of the samples it is important that you list all the different tastes you can detect in your own words. Please do not feel that you can only use specific scientific labels – the more varied and descriptive your taste labels are the better!

Examples

Below are 2 examples to help you get the idea of how to use your vocabulary to describe tastes.

1. 5 people were given samples of coffee to taste and asked to list in their own words, terms which could be used to describe some or all of the coffees. The descriptions each person listed can be seen in the table below:

Assessor 1	**Assessor 2**	**Assessor 3**	**Assessor 4**	**Assessor 5**
Black treacle	Bitter	Cardboard	Bitter	Almond
Cardboard	Cooked	Musty/dusty	Chocolate	Green
Chemical	Fusty	Nutty	Coffee	Bitter
Chocolatey	Fragrant	Oily	Drains	Butter
Earthy	Mothballs	Burnt	Plastic	Cardboard
Mousy	Nutty	Sawdust	Roasted	Fishy
Nutty	Powedery	Sharp/Acidic	Smoky	Greasy
Sawdust	Smoky	Stale	Stale	Malty
Sweet	Drains	Vanilla	Sweet	Tea leaves
Tobacco	Bitter chocolate	Scented	Rancid	Toast
Urinals		Mouldy	Burnt	Caramel
Vanilla			Choking	Vanilla
Cigarette ashy				

2. 5 people were given samples of port to taste and asked to list in their own words, terms which could be used to describe some or all of the ports. The descriptions each person listed can be seen in the table below:

Assessor 1	**Assessor 2**	**Assessor 3**	**Assessor 4**	**Assessor 5**
Clean	Firm	Acidy	Green	Paper
Coarse	Coarse	Sweet	Fruity	Rich
Fruity	Tannin	Chocolate	Taint	Harsh
Green	Crisp	Sugary	Mature	Green
Acidic	Hard			Soft
	Sour			

Rating sheet for perception of individually-generated taste qualities in fat – Study 3

Please rate the sample for each of the taste attributes. For each taste quality mark the line at the point you think best describes the taste. There is no right or wrong answer so please be completely honest.

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

------------------: Not at all — Extremely

Please rate how strong you feel the overall taste and flavour of the sample is:

Barely detectable — Strongest imaginable

Please indicate how much you like the taste of the sample:

Not at all — Extremely

Please indicate how much you like the texture of the sample:

Not at all — Extremely

Free Choice Profiling taste qualities response sheet – Study 3

Please taste each sample and make a list of as many different terms as you think would be needed to describe the flavours and taste of some or all of the samples. There is no right or wrong answer so please be completely honest. The most important thing is that you develop a varied list which best describes the tastes you perceive:

Appendix 3

Food Preference Questionnaire

Please select from the following list of foods, the food item which you would most enjoy eating as a snack:

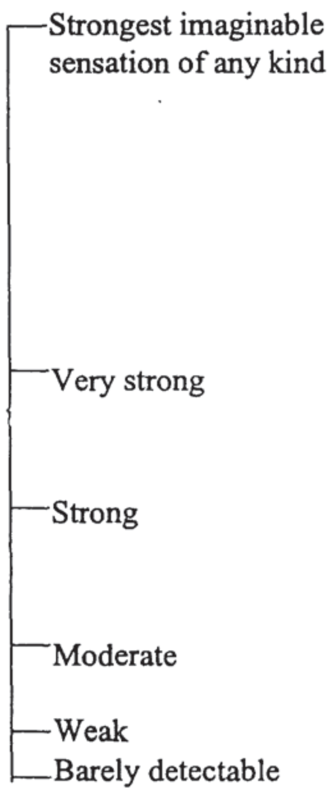
- Biscuits
- Cake
- Crisps
- Salted nuts
- Ice cream
- Fruit full-fat yoghurt
- Pizza slice
- Sausage roll
- Chips
- Piece of fried chicken

Labelled Magnitude Scale for rating perceived intensity of PROP – Studies 4 and 5

The line scale below can describe every sensation you've ever experienced in your whole life. The label at the top "strongest imaginable sensation of any kind" describes the strongest sensations you've ever experienced. For example, looking directly at the sun, the worst toothache you've ever had, the sound of a jet plane flying just over your head, a burn from a cooker ring.

You'll be given a small piece of paper to taste by putting it on the tip of your tongue (keep it there for about 5-10 seconds and then take it out). I'd like you to rate how strong or weak you think this tastes on the scale by putting a cross on the line. Think about how it tastes *in comparison with the strongest sensation you've ever experienced.*

The taste may build up slowly or may be perceived immediately. Rate the intensity of the taste when it is at maximum.



Appendix 4

Questionnaire to establish intake of basic fats and oils – Study 6

Please indicate what type of fat you most regularly use for cooking (circle the appropriate item/s):

Beef dripping

Butter

Corn oil

Grapeseed oil

Groundnut oil

Lard

Margerine

Rapeseed oil

Sesame oil

Sunflower oil

Vegetable oil

Walnut oil

Other: (please specify) ————————————

Please indicate how regularly you the fat/s for cooking (circle appropriate response):

Fat: ————————

Never	Rarely	Once a month	2-3 times a month	1 – 2 times a week	3 – 4 times a week	5 – 6 times a week	Every day	More than once a day

Fat: ————————

Never	Rarely	Once a month	2-3 times a month	1 – 2 times a week	3 – 4 times a week	5 – 6 times a week	Every day	More than once a day

Fat: ————————

Never	Rarely	Once a month	2-3 times a month	1 – 2 times a week	3 – 4 times a week	5 – 6 times a week	Every day	More than once a day

Dieting status and behaviour questionnaire – Study 6

Please answer the following questions. All information will be strictly confidential so please be as honest as possible! If you have any questions or are unsure about anything please ask.

Age: ——— years

Gender: Male —— Female ——

Do you smoke? Yes —— No ——

Are you a vegetarian? Yes —— No ——

Do you have any other special dietary requirements? If so please specify:

____

____

Are you currently dieting? Yes —— No ——

Have you ever dieted? Yes —— No ——

If so, how often do you diet? Please mark the scale at the point which best describes how frequently you diet.

Always |————————————————————| Never

When dieting how successful are you in reaching your target weight? Please mark the scale at the point which best describes your success.

Extremely successful |————————————————————| Not at all successful

How successful are you in maintaining your target weight? Please mark the scale at the point which best describes your success.

Extremely successful |————————————————————| Not at all successful

What is your height? ————

What is your weight? ————

Food Frequency Questionnaire – Study 6

Please tick the relevant box indicating how regularly you eat each of the following foods:

	Never	Rarely	Once a month	2 –3 times a month	1 – 2 times a week	3 – 4 times a week	5 – 6 times a week	Every day	More than once a day
Avocado									
Bacon									
Beef									
Burgers									
Biscuits									
Brie									
Butter									
Cakes or pastries									
Cheddar cheese									
Chicken									
Chips									
Coconut									
Cream									
Cream cheese									
Cream crackers									
Crème fraiche									
Crisps									
Croissants									
Curries									
Custard									
Dark chocolate									
Donuts									
Duck									
Eggs									
Fish 'n' chips									
Fried rice									
Fried breakfast									
Fromage frais									
Ice cream									
Lamb									
Margarine									
Marscarpone cheese									
Mayonnaise									
Milk chocolate									
Peanuts									
Peanut butter									
Pesto									
Pizza									
Popcorn									
Pork									
Roast dinner									
Salad dressing									
Sausages									
Savoury pies (i.e. meat)									
Semi-skimmed milk									
Skimmed milk									
Sour cream									
Stilton									

Sweet pies (i.e. apple)									
Taramasalata									
White chocolate									
Whole milk									
Yoghurt									

Appendix 5

Food Frequency Questionnaire – Study 7

Please tick the relevant box indicating how regularly you eat each of the following foods:

	Never	Rarely	Once a month	2 – 3 times a month	1 – 2 times a week	3 – 4 times a week	5 – 6 times a week	Every day	More than once a day
Alcohol									
Avocado									
Bacon									
Baked potatoes									
Beef									
Biscuits									
Boiled potatoes									
Boiled rice									
Brie									
Burgers									
Butter									
Cakes or pastries									
Canned fish in brine									
Canned fish in oil									
Cheddar cheese									
Chicken									
Chilli									
Chips									
Coconut									
Coffee									
Coleslaw									
Cream									
Cream cheese									
Cream crackers									
Crème fraiche									
Crisp bread									
Crisps									
Croissants									
Curries									
Custard									
Dark chocolate									
Diet drinks									
Donuts									
Duck									
Eggs									
Fish 'n' chips									
Full sugar fizzy drinks									
Fried rice									
Fried breakfast									
Fromage frais									
Fruit									
Fruit juice									
Garlic									
Ham									
Honey									
Hot chocolate									

	Never	Rarely	Once a month	2 –3 times a month	1 – 2 times a week	3 – 4 times a week	5 – 6 times a week	Every day	More than once a day
Ice cream									
Jam									
Kidney									
Lamb									
Liver									
Margarine									
Marmalade									
Marscarpone cheese									
Mayonnaise (light)									
Mayonnaise (full fat)									
Milk chocolate									
Pasta with cream based sauce									
Pasta with tomato based sauce									
Peanuts									
Peanut butter									
Pesto									
Pizza									
Pork									
Roast dinner									
Salad									
Salad cream									
Salad dressing									
Salted popcorn									
Sausages									
Savoury pies									
Semi-skimmed milk									
Skimmed milk									
Sour cream									
Stilton									
Sweet pies									
Sweet popcorn									
Taramasalata									
Tea									
Turkey									
Veggie burgers									
White bread									
White chocolate									
Wholemeal bread									
Whole milk									
Yoghurt									

Food Habits Questionnaire

Please answer the following questions. If a question does not apply to the way you eat, check "not applicable." For example, if you do not eat chicken, circle "Not applicable" to "take the skin off chicken."

In the **PAST MONTH,** how often did you do any of the following.......

	Usually or Always	Often	Sometimes	Rarely or Never	Not Applicable
When eating chicken, have it baked or broiled?					
When eating chicken, take off the skin?					
Use a meatless sauce on spaghetti or pasta?					
When eating red meat, eat only small portions?					
When eating red meat, trim off all visible fat?					
Have a vegetarian meal?					
Eat fish or chicken instead of red meat?					
Use very low-fat (1%) or non-fat milk?					
Eat special, low-fat or diet cheeses?					
Eat frozen yoghurt or sorbet instead of ice cream?					
Put butter or margarine on cooked vegetables?					
Eat boiled or baked potatoes without butter or margarine?					
Use low-calorie, instead of regular, salad dressing or mayonnaise?					
Put sour cream, cheese or other sauces on vegetables or potatoes?					
Have only fruit for dessert?					
Eat at least two vegetables (not green salad) at dinner?					
Snack on raw vegetables instead of crisps?					
Eat bread or rolls without butter or margarine?					

Dutch Eating behaviours Questionnaire – Study 7

	Never	Seldom	Sometimes	Often	Very often
1. When you have put on weight do you eat less than you usually do?					
2. Do you try to eat less at mealtimes than you would like to eat?					
3. How often do you refuse food or drink offered you because you are concerned about your weight?					
4. Do you watch exactly what you eat?					
5. Do you deliberately eat foods that are slimming?					
6. When you have eaten too much, do you eat less than usual the following day?					
7. Do you deliberately eat less in order not to become heavier?					
8. How often do you try not to eat between meals because you are watching your weight?					
9. How often in the evenings do you try not to eat because you are watching your weight?					
10. Do you take your weight into account with what you eat?					
11. Do you have a desire to eat when you are irritated?					
12. Do you have a desire to eat when you have nothing to do?					
13. Do you have a desire to eat when you are depressed or discouraged?					
14. Do you have a desire to eat when you are feeling lonely?					
15. Do you have a desire to eat when somebody lets you down?					
16. Do you have a desire to eat when you are cross?					
17. Do you have a desire to eat when something unpleasant is about to happen?					
18. Do you get the desire to eat when you are anxious, worried or tense?					
19. Do you have a desire to eat when things are going against you or have gone wrong?					
20. Do you have a desire to eat when you are frightened?					
21. Do you have a desire to eat when you are disappointed?					

22. Do you have a desire to eat when you are emotionally upset?					
23. Do you have a desire to eat when you are bored or restless?					
24. If food tastes good to you do you eat more than usual?					
25. If food smells good and looks good do you eat more than usual?					
26. If you see or smell something delicious do you have the desire to eat it?					
27. If you have something delicious to eat do you eat it straight away?					
28. If you see others eating do you also want to eat?					
29. Do you eat more than usual when you see others eating?					
30. When preparing a meal are you inclined to eat something?					
31. If you walk past the bakers do you have the desire to buy something delicious?					
32. If you walk past a snackbar or café do you have the desire to buy something delicious?					
33. Can you resist eating delicious food?					

Appendix 6

Food Preference Questionnaire – Studies 5 and 8

Please mark the line at the relevant point, indicating how much you like each of the following items. If the item is something you have never tried please circle "not tried."

Avocado: Extremely ———— Not at all Not tried

Bacon: Extremely ———— Not at all Not tried

Beef : Extremely ———— Not at all Not tried

Burgers: Extremely ———— Not at all Not tried

Biscuits: Extremely ———— Not at all Not tried

Brie: Extremely ———— Not at all Not tried

Butter: Extremely ———— Not at all Not tried

Cakes or pastries: Extremely ———— Not at all Not tried

Cheddar cheese: Extremely ———— Not at all Not tried

Chicken: Extremely ———— Not at all Not tried

Chips: Extremely ———— Not at all Not tried

Coconut: Extremely ———— Not at all Not tried

Cream: Extremely ———— Not at all Not tried

Cream cheese: Extremely — Not at all | Not tried

Cream crackers: Extremely — Not at all | Not tried

Crème fraiche: Extremely — Not at all | Not tried

Crisps: Extremely — Not at all | Not tried

Croissants: Extremely — Not at all | Not tried

Curries: Extremely — Not at all | Not tried

Custard: Extremely — Not at all | Not tried

Dark chocolate: Extremely — Not at all | Not tried

Donuts: Extremely — Not at all | Not tried

Duck: Extremely — Not at all | Not tried

Eggs: Extremely — Not at all | Not tried

Fish ‘n’ chips: Extremely — Not at all | Not tried

Fried rice: Extremely — Not at all | Not tried

Fried breakfast: Extremely — Not at all | Not tried

Fromage frais: Extremely — Not at all | Not tried

Ice cream: Extremely — Not at all | Not tried

Lamb: Extremely — Not at all | Not tried

Margarine: Extremely — Not at all | Not tried

Marscarpone cheese: Extremely — Not at all | Not tried

Mayonnaise: Extremely — Not at all | Not tried

Milk chocolate: Extremely — Not at all | Not tried

Peanuts: Extremely — Not at all | Not tried

Peanut butter: Extremely — Not at all | Not tried

Pesto: Extremely — Not at all | Not tried

Pizza: Extremely — Not at all | Not tried

Popcorn: Extremely — Not at all | Not tried

Pork: Extremely — Not at all | Not tried

Roast dinner: Extremely — Not at all | Not tried

Salad dressing: Extremely — Not at all | Not tried

Sausages: Extremely — Not at all | Not tried

Savoury pies: (i.e. meat) Extremely — Not at all | Not tried

Semi-skimmed milk: Extremely — Not at all | Not tried

Skimmed milk: Extremely — Not at all | Not tried

Sour cream: Extremely — Not at all | Not tried

Stilton: Extremely — Not at all | Not tried

Sweet pies: (i.e. apple) Extremely — Not at all | Not tried

Taramasalata: Extremely — Not at all | Not tried

White chocolate: Extremely — Not at all | Not tried

Whole milk: Extremely — Not at all | Not tried

Yoghurt: Extremely — Not at all | Not tried

Appendix 7

Food Preference Questionnaire – Study 9

Please mark the line at the relevant point, indicating how much you like each of the following items. If the item is something you have never tried please circle "not tried."

Alcohol: Not at all ———— Extremely Not tried

Avocado: Not at all ———— Extremely Not tried

Bacon: Not at all ———— Extremely Not tried

Baked potatoes Not at all ———— Extremely Not tried

Beef: Not at all ———— Extremely Not tried

Biscuits: Not at all ———— Extremely Not tried

Boiled potatoes Not at all ———— Extremely Not tried

Boiled Rice: Not at all ———— Extremely Not tried

Brie: Not at all ———— Extremely Not tried

Burgers: Not at all ———— Extremely Not tried

Butter: Not at all ———— Extremely Not tried

Cakes or pastries: Not at all ———— Extremely Not tried

Canned fish in brine: Not at all ———— Extremely Not tried

Please mark the line at the relevant point, indicating how much you like each of the following items. If the item is something you have never tried please circle "not tried."

Alcohol: Not at all — Extremely Not tried

Avocado: Not at all — Extremely Not tried

Bacon: Not at all — Extremely Not tried

Baked potatoes Not at all — Extremely Not tried

Beef: Not at all — Extremely Not tried

Biscuits: Not at all — Extremely Not tried

Boiled potatoes Not at all — Extremely Not tried

Boiled Rice: Not at all — Extremely Not tried

Brie: Not at all — Extremely Not tried

Burgers: Not at all — Extremely Not tried

Butter: Not at all — Extremely Not tried

Cakes or pastries: Not at all — Extremely Not tried

Canned fish in brine: Not at all — Extremely Not tried

Canned fish in oil: Not at all — Extremely | Not tried

Cheddar cheese: Not at all — Extremely | Not tried

Chicken: Not at all — Extremely | Not tried

Chilli: Not at all — Extremely | Not tried

Chips: Not at all — Extremely | Not tried

Coconut: Not at all — Extremely | Not tried

Coffee: Not at all — Extremely | Not tried

Coleslaw: Not at all — Extremely | Not tried

Cream: Not at all — Extremely | Not tried

Cream cheese: Not at all — Extremely | Not tried

Cream crackers: Not at all — Extremely | Not tried

Crème fraiche: Not at all — Extremely | Not tried

Crisp bread: Not at all — Extremely | Not tried

Crisps: Not at all — Extremely | Not tried

Croissants: Not at all — Extremely | Not tried

Curries: Not at all — Extremely | Not tried

Custard: Not at all — Extremely | Not tried

Dark chocolate: Not at all — Extremely | Not tried

Diet drinks: Not at all — Extremely | Not tried

Donuts: Not at all — Extremely | Not tried

Duck: Not at all — Extremely | Not tried

Eggs: Not at all — Extremely | Not tried

Fish 'n' chips: Not at all — Extremely | Not tried

Full sugar fizzy drinks: Not at all — Extremely | Not tried

Fried rice: Not at all — Extremely | Not tried

Fried breakfast: Not at all — Extremely | Not tried

Fromage frais: Not at all — Extremely | Not tried

Fruit: Not at all — Extremely | Not tried

Fruit juice: Not at all —————— Extremely Not tried

Garlic: Not at all —————— Extremely Not tried

Green Veg: Not at all —————— Extremely Not tried

Ham: Not at all —————— Extremely Not tried

Honey: Not at all —————— Extremely Not tried

Hot chocolate: Not at all —————— Extremely Not tried

Ice cream: Not at all —————— Extremely Not tried

Jam: Not at all —————— Extremely Not tried

Lamb: Not at all —————— Extremely Not tried

Margarine: Not at all —————— Extremely Not tried

Marscarpone cheese: Not at all —————— Extremely Not tried

Marmalade: Not at all —————— Extremely Not tried

Mayonnaise: (light) Not at all —————— Extremely Not tried

Mayonnaise: (full fat) Not at all —————— Extremely Not tried

Milk chocolate: Not at all |———| Extremely Not tried

Pasta with cream based sauces Not at all |———| Extremely Not tried

Pasta with tomato based sauces: Not at all |———| Extremely Not tried

Peanuts: Not at all |———| Extremely Not tried

Peanut butter: Not at all |———| Extremely Not tried

Pesto: Not at all |———| Extremely Not tried

Pizza: Not at all |———| Extremely Not tried

Pork: Not at all |———| Extremely Not tried

Roast dinner: Not at all |———| Extremely Not tried

Salad: Not at all |———| Extremely Not tried

Salad cream: Not at all |———| Extremely Not tried

Salad dressing: Not at all |———| Extremely Not tried

Salted popcorn: Not at all |———| Extremely Not tried

Sausages: Not at all |———| Extremely Not tried

Savoury pies: (i.e. meat) — Not at all ———— Extremely — Not tried

Semi-skimmed milk: — Not at all ———— Extremely — Not tried

Skimmed milk: — Not at all ———— Extremely — Not tried

Sour cream: — Not at all ———— Extremely — Not tried

Stilton: — Not at all ———— Extremely — Not tried

Sweet pies: (i.e. apple) — Not at all ———— Extremely — Not tried

Sweet popcorn: — Not at all ———— Extremely — Not tried

Taramasalata: — Not at all ———— Extremely — Not tried

Tea: — Not at all ———— Extremely — Not tried

Turkey: — Not at all ———— Extremely — Not tried

Veggie meals: — Not at all ———— Extremely — Not tried

White bread: — Not at all ———— Extremely — Not tried

White chocolate: — Not at all ———— Extremely — Not tried

Wholemeal bread: — Not at all ———— Extremely — Not tried

Whole milk: Not at all |———————| Extremely Not tried

Yoghurt: Not at all |———————| Extremely Not tried