A Study of the Sensory Characteristics of Food produced by the Sous Vide System: The Measure of Pleasure.

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Abstract

Consumers now demand higher quality in all aspects of life. This has had a particular effect on the food industry where the need for quality encompasses both food safety and sensory characteristics. The sous vide process was developed to produce food on a large scale but with superior sensory qualities compared to the products of cook-chill and cook-freeze systems.

This research aimed to determine whether the sous vide process could produce meals with superior sensory properties as claimed. A literature survey indicated that craft-based assessors (chefs) claimed improved qualities in sous vide products which were not consistently supported by sensory analysts (scientists). Empirical studies were conducted to test whether sous vide and conventionally processed dishes could be distinguished by untrained assessors in a controlled laboratory environment and with assessors in an ecologically valid environment, a restaurant. In the laboratory, the sous vide meals were easily distinguishable from and less acceptable than the conventionally produced dish. In the restaurant, few significant differences were found. Thus the ecologically valid environment of the restaurant where the many extrinsic factors affect consumers' perceptions, effectively masked differences between the sous vide and conventionally prepared meals.

To explore the reasons for this, a survey (n=188) was conducted to determine the relative importance of the intrinsic and extrinsic factors affecting the acceptability of foods when eating out. Results included a factor analysis which clearly showed components of 'customer care' had the greatest influence on the pleasure of eating out, followed by 'drink', and the absence of 'entertainment'. The factor which included 'enjoyment of food' was eleventh in the level of influence. Two scales were also devised to assess consumers' attitudes towards complaining about problems with meals and towards the technology used to produce them.

This work has demonstrated that although consumers assume that the intrinsic qualities of food are the most important facator giving them pleasure when eating out, many extrinsic factors will have a much greater influence on affecting their overall pleasure from the experience.

Dedicated to my parents, Tom and Dorothy.

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Author's declaration

Many aspects of the material submitted have been presented in the publications listed earlier.

Definitions and abbreviations used

Acceptable	'capable or worthy of being accepted', 'welcome or pleasing to the receiver', 'barely adequate'. (Longman 1984)
Acceptance	'the act of accepting, approval', 'the fact or state of being accepted or acceptable, acceptability'. (Longman 1984)
Affective	A term relating to the attractive as well as repulsive emotion aroused by a stimulus.
ANOVA	Analysis of variance.
Assessors	Those taking part in a sensory evaluation session.
Desirability Score	A value between 0 and 1 which is the geometric mean of several desirability values. Denoted by 'D'.
Desirability value	A value between 0 and 1 where 0 indicates the minimum acceptable level for a particular scale and 1 indicates the maximum acceptable. Intermediate values can be based on linear or non-linear interpolation. Denoted by 'd'.
FDA	Food and Drug Authority, U.S.A.
FNS	Food Neophobia Scale (Pliner and Hobden 1992) derived from responses to 5 positively and 5 negatively worded statements on behaviour towards eating new foods, each of which gives a score from 1 (low neophobic) to 7 (high neophobic). The total thus gives a score between 10 and 70.
Foodservice	A term for 'catering', originally American but now in wider use.
Hedonic	'of or characterised by pleasure'. (Longman 1984)
Hedonics	'a branch of psychology concerned with the study of pleasant and unpleasant sensations'. (Collins 1991)
Intolerance index	A number between 1 and 9 devised in this work to express a consumer's reaction to problems with meals, a low number indicating a low likelihood to complain and a high number a high likelihood to complain.
Liking	'favourable regard', 'fondness'. (Longman 1984) 'fondness', 'inclination, taste'. (Collins 1991)
Palatable	'agreeable to the palate or taste', 'agreeable to the mind'. (Longman 1984) 'agreeable to eat'. (Collins 1991)
Panellists	See assessors.
Perfection	'making or being perfect', 'freedom from fault or defect', 'unsurpassable accuracy or excellence'. (Longman 1984) 'state of being perfect', 'faultlessness'. (Collins 1991)
Pleasure	'a state or feeling of happiness or satisfaction', 'a source of happiness or satisfaction'. (Longman 1984)

	'enjoyment', 'satisfaction'. (Collins 1991)
	Synonyms:- 'delight' suggests a keener and evident, often fleeting pleasure. 'joy' suggests a deeper, longer lasting 'delight' often with spiritual connotations. 'delectation' and 'enjoyment' both stress the reaction to pleasure as opposed to the feeling itself, the first stressing the provision of entertainment and the second, conscious savouring of what pleases someone.
Prefer	'to choose or esteem above another.' (Longman 1984)
	'like better'. (Collins 1991)
Preference:	'being preferred'. (Longman 1984)
	Synonyms:- 'choice', 'favourite', 'first choice'. (Collins 1991)
SC	Social Class based on Occupation. I (Professional occupations), II (Managerial and technical occupations), IIIN (Skilled non-manual occupations), IIIM (Skilled manual occupations), IV (Partly skilled occupations), V (Unskilled occupations) (OPCS 1991)
SVAC	Sous Vide Advisory Committee, U.K.
sous vide	The French term for 'vacuum', literally 'under empty'.
Sous vide method/process/cooking, Cuisine en Papillote Sous Vide, Vacuum cooking, etc.	
	'an interrupted catering system in which raw or par-cooked food is sealed into a vacuumised laminated plastic pouch or container, heat treated by controlled cooking, rapidly cooled and then reheated for service after a period of chilled storage.' (SVAC 1991).
Systems approach	The concept of inputs being transformed into outputs through a particular process using feedback as a form of control to meet the system's objectives.
Technophobia index	An index number devised in this work to express a consumer's perception of newer methods of food preparation compared to conventional methods. Calculated by expressing the average of the consumer's acceptability scores for cook-freeze, cook-chill, sous vide, dehydrated and a mixture of these methods as a percentage of that consumer's acceptability score for conventional food preparation, the lower the index, the more technophobic the consumer.

1 Introduction

Over the last two decades consumer expectations for a higher quality of life have increased dramatically in Europe. Nowhere is this more apparent than in the demand for higher quality food particularly when eating away from home. Adopting a global definition of food quality [1], this increase encompasses not only the intrinsic properties of food but also the extrinsic elements of food service and provision [2]. The importance of such extrinsic factors has been demonstrated by their effect on consumer demand (Mark *et al.* 1981; Pierson *et al.* 1995) and food choice in the restaurant (Bell *et al.* 1994; Meiselman *et al.* 1994).

This rise in consumers' expectations and awareness has led to their reluctance to accept anything other than premium goods and services and hence the foodservice (catering) industry [3] is having to find solutions to meet a demand for optimum quality. Owing to considerable investment in 'systems' approaches in the 1960's and 1970's, the foodservice industry has placed considerable emphasis on processes such as cook-chill and cook-freeze to provide bulk production and storage (Millross *et al.* 1973; Light and Walker 1990). Although meeting changing and irregular needs, particularly in institutional feeding, these processes rarely meet the levels of acceptability now demanded by consumers at the premium end of the market (Cardello *et al.* 1996).

Consumer expectations of high quality have now permeated to levels of foodservice which use products of bulk production systems. These were previously thought satisfactory, but may now be considered unacceptable. Skills at the point of service to the consumer are frequently restricted to regeneration (reheating) and simple presentation of the previously cooked product, preserved by either chilling or freezing. Reluctant to invest in extensive craft skills, the industry was subsequently attracted by the development of the sous vide process. This process claimed to provide similar advantages to cook-chill and cook-freeze, i.e. extended shelf-life and limited skills input, and yet provide greatly enhanced sensory and nutritional quality which would meet consumer expectations of higher quality (Baird 1990).

Due to the relatively mild heat treatment, one of the factors contributing to the enhanced sensory and nutritional quality of sous vide products, there was caution regarding the microbiological safety of the process. This was understandable, particularly considering the prevailing climate of 'food scares' in the U.K. (Mintel

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[1] 'the composite of those characteristics that differentiate individual units of a product, and have significance in determining the degree of acceptability of that unit by the buyer.' (Kramer & Twigg, 1970).

[2] These extrinsic elements could include sensory, nutritional, safety, price, availability factors, eating environment, delivery, etc.

[3] The terms 'foodservice' and catering' are assumed to be interchangeable.

1997d, Fig. 1). The emphasis of early investigations into sous vide products therefore concentrated on microbiological safety and the claims of premium sensory quality, whilst still remaining a selling point, were assumed but largely unproven. Yet without scientific proof of their sensory superiority, these foods offered consumers and hence the foodservice industry little advantage over competing products already available on the market (Creed 1995).

Seeking scientific proof of sensory superiority involves studies of preference and acceptability, a field in which methods have been developed and are now well tried and tested (Piggott 1988; Lawless and Heymann 1998). Models of food acceptability and preference, incorporating both the intrinsic and extrinsic attributes of food have now been proposed (MacFie and Thomson 1994; Meiselman and MacFie 1996). Much of this work is based on the use of linear scales such as the hedonic scale proposed by Peryam and Pilgrim (1957). Whilst there are definable levels of preference and acceptability which may relate to the sensory superiority of premium foods, such measures cannot be regarded in isolation but should be considered within the environmental context in which the food is consumed (Meiselman 1992). Such contexts demand a comparative study of the intrinsic and extrinsic attributes of a meal specifically prepared to meet the demands of the premium market. Such a meal should take into account consumers' expectations and the level of anticipated satisfaction.

In order to design such a study it is necessary to consider the current state of knowledge of the sous vide process, the measurement of food acceptability and firstly the recent developments in consumer awareness and expectations as a function of evolving lifestyle and changing eating habits.

1.1 The development of eating out as a leisure activity

A number of factors have influenced changes in eating habits; these include changes in family structure, increased holiday travel abroad and redistribution of disposable income.

Within the family structure, meal preparation was traditionally the prerogative of the 'housewife' caring for a husband and children, but as women's career opportunities and employment levels have increased, the time available for food preparation has decreased. In 1960, women comprised 34.5 % of the working population; by 1996, this had risen to 46.1 % (Figure 1) (CSO 1968, 1976, 1987; ONS 1997a). Households with the typical family group of two adults and one or two children are also becoming less common in the U.K.; the proportion falling from 30 % of households in 1961 to 19 % in 1995/1996 (ONS 1997b). In parallel, the number of single person households rose by 21% between 1985 and 1996, with the average household size declining from 2.79 to 2.39 (Mintel 1996a, Fig. 3). More working women and decreasing average household size have contributed to the breakdown of the family meal with family members eating at different times or while occupied in other activities. This situation coincides with the wider availability of snack foods, individual meals and use of the microwave oven (Mintel 1996b, Fig. 4). Although behaviour may have changed, intentions have not; the proportion of those who still believe it is important to eat together has increased from 38 % in 1994 to 51 % in 1996 (Mintel 1996a, Fig. 65). It is a matter of conjecture whether these intentions will ultimately reverse this trend in meal pattern.

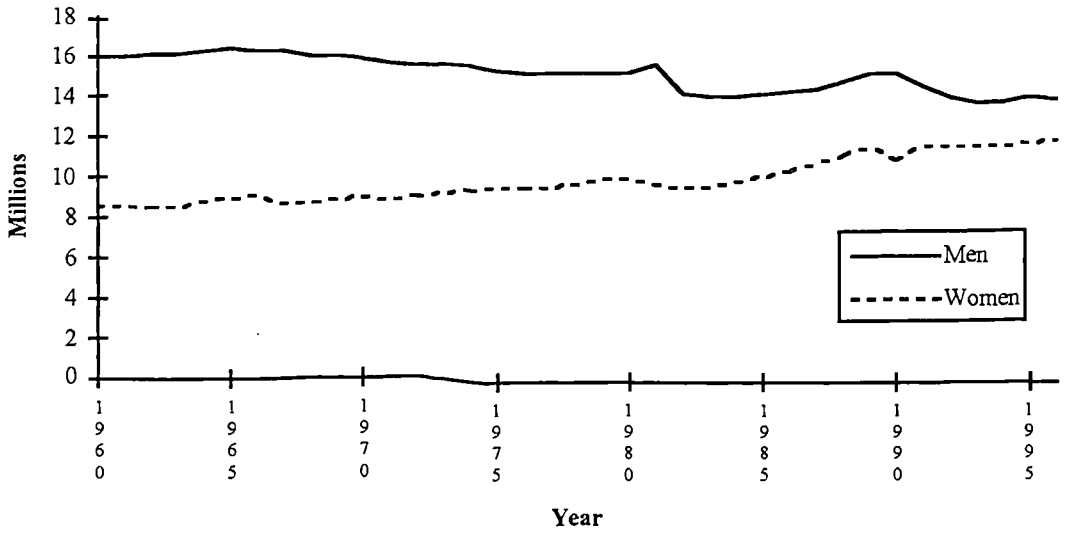

Figure 1. U.K. male and female working population from 1960 to 1996 (CSO 1968, 1976, 1987; ONS 1997a)

Holiday travel abroad has increased; in 1980 only 9% of adults took inclusive holidays abroad; by 1996 this had risen to 23% (Mintel 1997c, Fig. 6). This has increased the demand for a wider range of retail chilled prepared meals and also sustained the development of ethnic restaurants (Mintel 1998b). The affluent social classes who are most likely to travel abroad, class themselves as 'adventurous' compared to the less affluent groups who tend to be more 'traditional' in their outlook towards food (Mintel 1996a, Fig. 54).

In the U.K., personal disposable income increased by 15 % in real terms between 1992 and 1997 (Mintel 1998a, Fig. 1) which paralleled an increase in the size of the combined Social Classes (SC) I & II [4] from 7.4 m (17 % of the population) in 1980 to a forecast 10.9 m (23 %) in 2000 with a corresponding increase for the SC IIIN [5] from 9.9 m (22 %) to 13.6 m (28 %) (Figure 2). This growth in the size of the most affluent social classes who travel more and eat more adventurously, would be likely to increase spending on eating away from home.

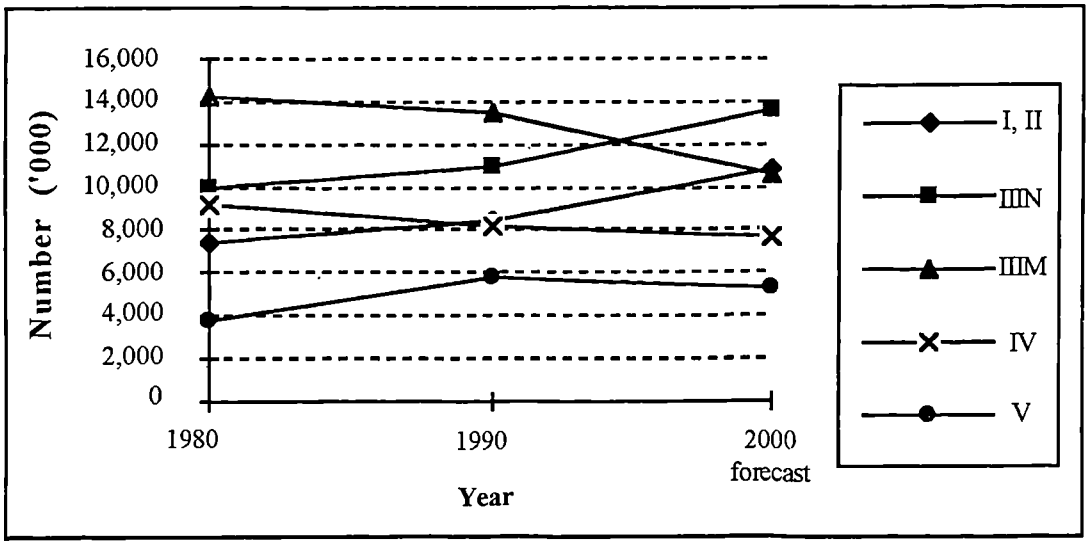

Figure 2. Changes in size of Social Class (SC) in U.K. from 1980 to 2000 (Mintel 1998a Fig. 3).

As personal disposable income has risen, spending in the U.K. on eating out has increased in real terms by 6 % between 1992 and 1997 (Mintel 1997b, Fig. 2). In addition, spending on pub catering rose from £m 3,700 in 1992 to £m 5,100 in 1997, an increase of 38 % and restaurant meals from £m 2,030 in 1992 to £m 2,602 in 1997, an increase of 28 % (Mintel 1997b, Fig. 3).

To summarise the consequences of changes in lifestyle: a larger number of working women, a smaller average household size, increased travelling abroad and a greater disposable income for the most affluent social groups, have led to changes in

[4] SC I and II broadly comprise professional and managerial occupations respectively.
[5] SC IIIN broadly comprises skilled non-manual occupations.

meal patterns, a desire for more convenient foods, an increased interest in ethnic foods and an increase in eating out. These consequences have resulted in new products from the food industry aiming to provide the consumer with 'convenience, high quality, freshness, authenticity, novelty and good taste' (Byrne 1997).

1.2 The consumer's demand for quality

In the next five years, it is predicted that quality will be a key factor in helping the eating out market to recover from the recent recession (Mintel 1997a), by combining themes and entertainment with quality food or foodservice to produce a 'quality experience'.

An early investigation into this 'quality experience', applied to an eating situation, used Lancaster's theory of consumer demand (Lancaster 1966) by Mark *et al.*, (1981) studying the pub/beer combination. They concluded that the sensory quality of beer was only one attribute contributing to the individual's choice of the most acceptable pub/beer package. Further analysis showed that the population comprised two groups separated according to the preferred beer type. This revealed a shift in the relative importance of attributes with one group regarding beer quality to be of paramount importance and the other, the social aspects of the pub/beer package (Pierson *et al.* 1995).

Consumers' increased interest in eating out and the quality of food have caused the food manufacturing and foodservice industries to develop innovative technologies. These systems-based approaches for processing and packaging food have been designed to take over many of the tasks of preparing and cooking food which had usually taken place in kitchens either in the home, hotels or restaurants by using ready prepared meals.

1.3 Chilled prepared meals in the foodservice industry

1.3.1 The market for chilled prepared meals

The rising demand for higher quality foods from consumers with more disposable income has paralleled the growth in the retail chilled ready meals market both in the United Kingdom and in France (Table 1). These products have become known as 'home meal replacements' (Caira 1998; LaRivière 1998).

	United Kingdom		France	
	Value (£m)	% change (year on year)	Value (FFm)	% change (year on year)
1990	-	-	513	-
1991	205	-	562	+9.6
1992	238	+16.1	599	+6.6
1993	267	+12.2	626	+4.5
1994	288	+7.9	689	+10.1
1995	310	+7.6	785	+13.9
1996	338	+9.0	-	-
1997	364	+7.7	-	-

Table 1. The value of the retail markets for chilled ready meals in the United Kingdom and France (Mintel 1998c; Mitchell 1997).

Using chilled ready prepared meals consumed at home has coincided with an increased interest in using ready meals in the foodservice market. In foodservice, sales of chilled foods have risen from £ 46m (25 % of total) in 1994 to £ 70m (33 %) in 1996 (Mintel 1997b, Fig. 11). It is forecast that the total market will rise by 29% in value by the year 2001 representing a growth rate of 9% in real terms (Mintel 1997b, Fig. 20). Much of this growth has been driven by organisations cutting costs and contracting out their foodservice operations. In turn, contract caterers have had to operate more efficiently by using economies of scale and buying in ready prepared meals and meal components from specialist manufacturers (Mintel 1997b). Between 1989 and 1996 the number of outlets managed by contract caterers increased by 88 % and the number of meals they served by 130 % (Mintel 1997b, Fig. 4). Contract caterers were also the largest users of ready prepared meals in the foodservice sector (Mintel 1997b, Fig. 12). As ready prepared meals become more widely used, understanding the principles of operation of the bulk production systems of operation and the way they can affect sensory and nutritional quality becomes increasingly important for the foodservice operator trying to satisfy the consumer.

1.3.2 The reaction of the foodservice industry to consumer demands

Using the systems approach [6] - the 'industrialisation' of food production - has been one reaction of the foodservice industry to increase efficiency by minimising labour, equipment and energy costs. Minimising these resource costs has been successful but simultaneously satisfying consumers' demands for quality and menu variety has been more difficult (Light and Walker 1990).

Traditionally, food has been prepared, cooked and served in a rapid sequence (Figure 3). Once inputs of raw food materials enter the system, they must undergo the entire process. Therefore, problems in predicting requirements and the short shelf-life of the food once cooked can lead to high wastage levels. In addition, skilled staff can only work when food is required, often at unsocial hours with intermittent and inefficient use of other resources.

Figure 3. Systems diagrams for a traditional cook-serve foodservice system.

New systems such as cook-chill and cook-freeze, are based on centralised production units supplying satellite kitchens for staff feeding or chains of commercial restaurants. The success of such systems depends on the 'time buffer' - 'a stage during which the food is preserved safely and conveniently, usually by chilling or freezing.' (Creed 1989) (Figure 4). However attempts to apply this systems approach to large scale production have not produced food perceived by consumers as being of high quality (Cardello *et al.* 1996). It has been shown that what happens to food during the time buffer and especially during reheating for service to the consumer, greatly affects meal quality and therefore the success of the foodservice system (Light and Walker 1990).

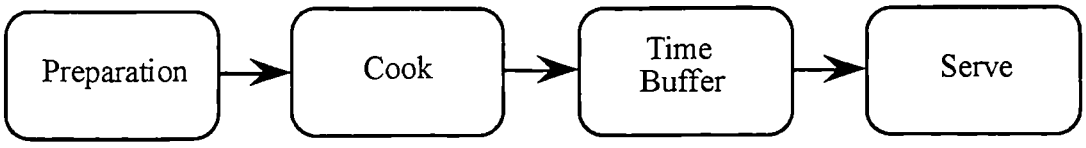

Figure 4. Systems diagrams for a modern foodservice system incorporating a time buffer.

[6] The concept of inputs being transformed into outputs through a particular process using feedback as a form of control to meet the system's objectives (based on papers in: Open Systems Group, 1981).

1.3.3 Potential advantages of a time buffer

Introducing a time buffer between the cooking and service stages, aims to solve many of the problems of the cook-serve system (Figure 3). In theory:

- Staff can work normal hours without peaks of activity at meal times.
- Staff can work more efficiently with planned production.
- Less equipment can be used for longer periods for the same output of meals.
- Food production can be centralised to avoid duplicating equipment and skilled labour in a large number of small kitchens.
- Energy can be used more efficiently in heating equipment by minimising the number of warming-up times.
- Economies of scale can cut food costs.
- Meals can be reheated when required leading to less food wastage.
- Staff with less skill can be employed to reheat and serve food in satellite [7] kitchens.

However, these advantages depend on a reliable method of preserving and distributing the cooked food during the time buffer hence causing a minimal effect on its microbiological, sensory and nutritional qualities. The following points are imperative for judging the success of a foodservice system using a time buffer:-

- The microbial load of the raw material inputs must be low as the heat processing only eliminate a proportion of the micro-organisms originally present.
- Safety problems arising from the potential for growth of pathogenic and spoilage micro-organisms must be minimised.
- Sensory problems caused by colour and texture changes, separation of food components, drying out, rancidity and development of off-flavours must be minimised.
- Reduction in nutritional levels during storage and reheating especially for the heat-labile B group vitamins must be minimised.

Assuming the previous points are in place, the acceptability of the reheated product to the consumer should be the final criterion for judging the success of any preservation system.

[7] The small 'satellite' kitchens are intended for reheating ready prepared meals near the point of consumption.

1.3.4 Methods to create a time buffer

Some early efforts to incorporate a time buffer for foodservice used the cook-freeze system (Millross *et al.* 1973) (Figure 5). Later, cook-chill systems (Figure 6) were promoted by manufacturers of large-scale cooking and refrigeration equipment working with the electricity industry (Electricity Council 1982). Similarly for the sous vide process (Figure 7), manufacturers of specialised equipment for vacuum packing, cooking, cooling, chilled storage, reheating and packaging have co-operated in creating complete systems.

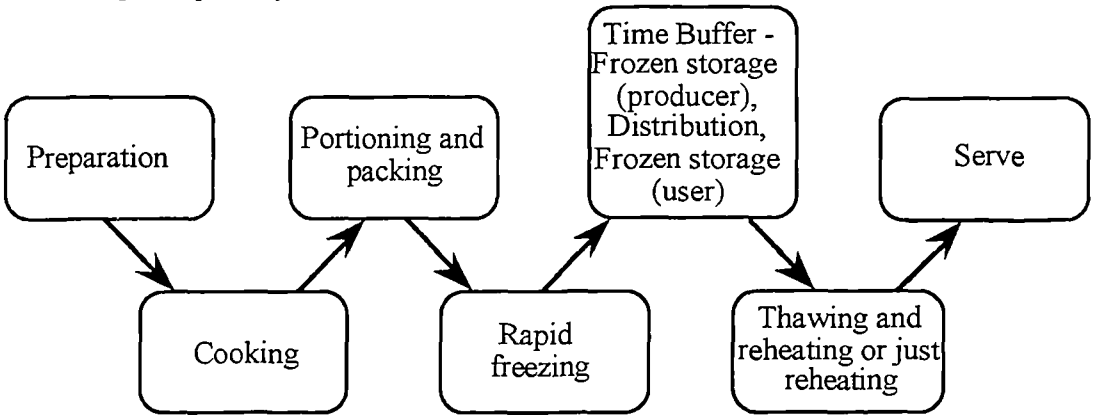

Figure 5. Systems diagrams for a cook-freeze system.

Other foodservice systems which have used chilling and chilled storage as the time buffer, the Swedish Nacka system (Bjorkman and Delphin 1966), the American AGS system (McGuckian 1969) and the CapKold bulk production system (Daniels 1988) have been reviewed by Light and Walker (1990).

The question that must be asked when introducing any foodservice system, is whether a specific combination of equipment is best at providing the menu range and quality of food for the consumers' needs. It may have particular constraints, thus reducing the anticipated flexibility of operation, choice of menu items and perceived quality. The sous vide process aimed to overcome these constraints.

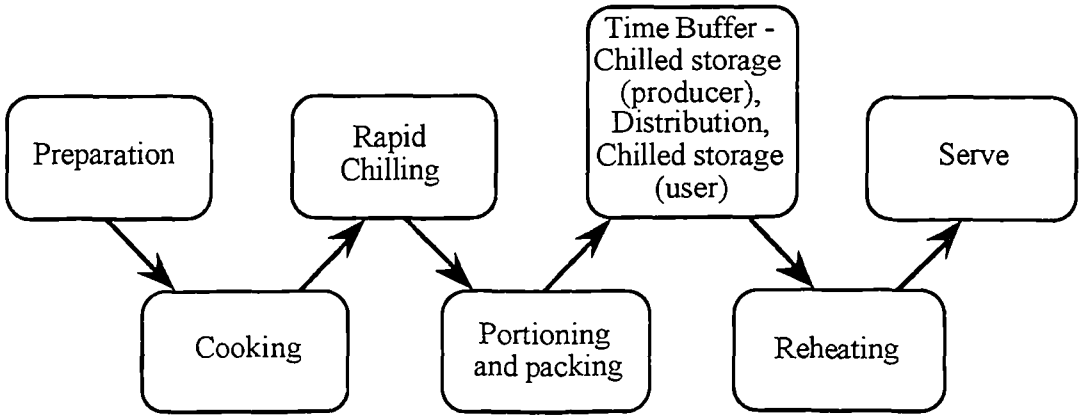

Figure 6. Systems diagrams for a cook-chill system.

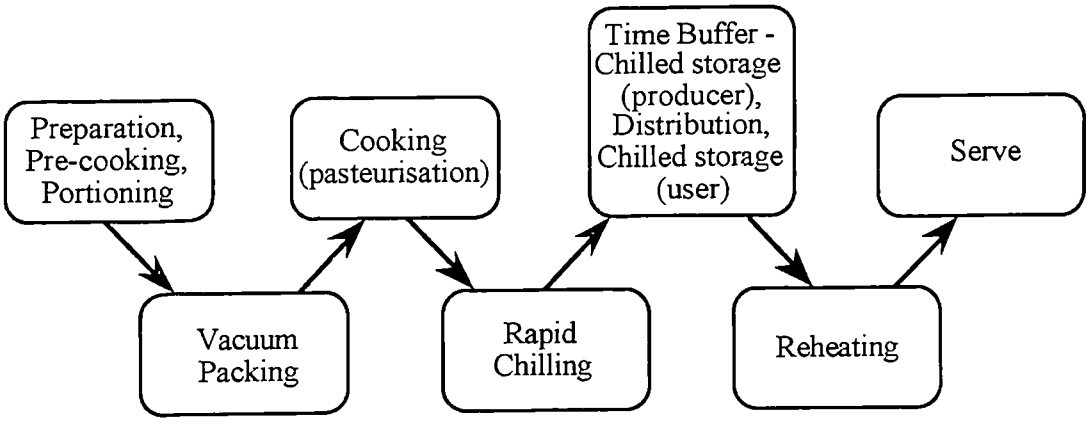

Figure 7. Systems diagrams for a sous vide system.

1.4 The development of the sous vide process

The sous vide process of food processing and preservation (Figure 7) has been proposed as one system where efficiency of operation and consumer demands for high quality may be satisfied. This section discusses how this has been achieved and in doing so, critically evaluates the process's strengths and limitations.

1.4.1 Background to the sous vide process

The concept of enclosing food before cooking to prevent the escape of food juices and flavours during cooking has long been practised. Examples of this practice include *en papillote* in French cuisine and using a salt dough to enclose foods (Escoffier 1907).

The development of the sous vide process in 1974 is generally credited to Georges Pralus, a French chef (Pralus 1985). In the sous vide process, the packaging physically retains components of food flavour, nutrients and moisture. It also excludes oxygen and its influence in the formation of off-flavours and prevents recontamination of the cooked food during chilling and storage. In addition, the relatively low cooking temperatures used for pasteurisation in the sous vide process lead to lower breakdown rates at the molecular level for many nutrients and volatile flavour components. Following this, the rapid chilling and chilled storage minimise the growth of micro-organisms. However, a patent by Ready (1971) assigned to W.R. Grace, the American packaging company, contained the basic concepts of the process. This patent suggested vacuum packing raw food materials in laminated plastic packaging (polyethylene with Mylar, nylon or saran) able to withstand the temperatures of the hot water used for cooking, followed by cooling and storage. However, other industrial systems devised by food technologists had also contained elements of the sous vide process, for example: Nacka (Bjorkman and Delphin 1966), AGS (McGuckian 1969), ready-prepared potatoes (Poulsen 1978), cook-in-bag meats (Buck *et al.* 1979), cook-in hams (Anon. 1981) and the CapKold system (Daniels 1988).

It would appear therefore that the declaration made by its originator that the sous vide process was his 'discovery' was somewhat exaggerated (Pralus 1985). Despite this, Pralus must be given credit for bringing these elements together and through his culinary expertise applying the sous vide concept to practical problems of recipe development. Overcoming these problems required the creative craft input of a chef and was beyond the reach of the food technologists who devised the industrial systems mentioned above. It is arguably these circumstances surrounding the development of the sous vide process and not the process itself which made sous vide unique as a foodservice system. Firstly, unlike previous time-interrupted systems,

sous vide was introduced by a charismatic French chef whose enthusiastic claims could be regarded as part of his craft. Secondly, the French term for the process connected it with French *haute cuisine* regarded by many as foremost in the world. Thirdly, it could be argued that the French regulations on heat treatments for pre-cooked foods, using a different target bacterium, were not so stringent as in other countries (Table 2). Under such circumstances, Georges Pralus could claim an excellent retention of sensory and nutritional qualities and, given his craft and presentational skills, could offer convincing evidence of the superiority of sous vide products.

Pralus adopted an emotional attitude towards the process, referring to it as *'Une histoire d'amour'* (a love story) in the title of the book on his development work and recipes (Pralus 1985). He emphasised the requirement for the highest quality raw materials, strict hygiene standards and correct procedures and temperatures for cooking, cooling, storage and reheating. He condensed these ideas into 'ten commandments' in his search to produce the perfect meal.

Over the last twenty years, the sous vide process has often been acclaimed for the excellent sensory qualities of the dishes produced (summarised in Appendix A.1). Unfortunately, the minimal heat treatment and use of vacuum packing have been claimed to offer perfect growth conditions for pathogenic bacteria such as *Clostridium botulinum* (Miller 1988). In 1988 the FDA (Food and Drug Authority) in the U.S.A. issued warnings about the use of sous vide and the potential dangers to public health (Schwarz 1988). They used legislation, originally brought in to discourage home canning with the associated risk of botulism, to prevent the production of sous vide products by foodservice operators for retail sale. The FDA only permitted the manufacture of sous vide products in a professionally designed and managed environment using experienced personnel (Schwarz 1988).

This FDA action was the turning point for the focus of discussion on the sous vide process to move from sensory quality to microbiological safety. Table 2 illustrates some combinations of time and temperature in the core of the product during the pasteurisation stage deemed necessary by researchers for the sous vide process to produce 'safe' food. Ignoring any effects on sensory quality, these heat treatments were based purely on microbiological data for various types of bacterium and have gradually become more severe (Table 2). So the main factor which brought sous vide to prominence seemed almost secondary in the research efforts to find a method to guarantee product safety.

In the U.K. and U.S. food industries, the term 'sous vide' has come to mean a process in which raw food is vacuum packed and then cooked at low temperatures although several other names such as pouch cooking, vacuum cooking have been

used (Creed 1992). A widely accepted definition [8] came from SVAC (Sous Vide Advisory Committee) a group formed in 1989 in the U.K. The various advantages and disadvantages of the sous vide system and the reasons contributing to the success or failure of sous vide product manufacturers (summarised in Appendix A.2) have been well documented (Baird 1990; Sheard and Church 1992; Schellekens and Martens 1992a, b). The wide range of applications of the sous vide process are summarised in Appendix A.3 and world activity in the areas of sous vide production, application, education and research in Appendix A.4.

Heat treatment (Specified centre temperature and time)	**Intention**	**Target bacterium**	**Source**
70°C for 40 minutes 70°C for 100 minutes 70°C for 1000 minutes	6 days chilled shelf-life 21 days chilled shelf-life 42 days chilled shelf-life	*Enterococcus faecalis*	Ministère de l'Agriculture 1974, 1988, (French regulations)
70°C for 2 minutes	5 days chilled shelf-life	*Listeria monocytogenes*	DoH 1989
80°C for 26 minutes or 90°C for 4.5 minutes, etc.	up to 8 days chilled shelf-life	*Clostridium botulinum type E*	SVAC,1991
90°C for 10 minutes	>10 days chilled shelf-life	*Clostridium botulinum*	ACMSF 1992
70°C for 2 minutes	short shelf-life and reliable storage temperature	*Listeria monocytogenes*	Gould 1996 (ECFF Botulinum Working Party), Betts 1996
90°C for 10 minutes	longer shelf-life, >10 days chilled shelf-life	*Clostridium botulinum*	Gould 1996 (ECFF Botulinum Working Party), Betts 1996

Table 2. Heat treatments recommended or suggested for sous vide products.

1.4.2 Anecdotal and scientific evidence for excellence of sensory quality

Many comments provide ample anecdotal evidence that the sous vide process produces food of a high sensory quality (Appendix A.1) with the added supposition that its nutritional qualities must be equally high. They can be summarised as: 'the sous vide process produces a food with a better flavour, colour, texture and nutrient retention than conventionally-cooked foods'. However, this evidence was proposed primarily on the basis of the professional judgement of those who had already made a commitment in time, resources and capital to the production of sous vide foods (Creed 1995).

A review of scientific research on sensory aspects of sous vide processed products based on meat, poultry, fish, fruit and vegetables is given in Appendix B. This surveys a range of sensory techniques, types of product, types of comparison

[8] 'an interrupted catering system in which raw or par-cooked food is sealed into a vacuumised laminated plastic pouch or container, heat treated by controlled cooking, rapidly cooled and then reheated for service after a period of chilled storage.' (SVAC 1991).

and range of heat treatments and storage times. It also compares the aspects studied and whether the results were positively, neutrally or negatively disposed towards the sous vide process. Results of research on other processes of food preparation which use the same principle as the sous vide process (section 1.3.4) are also included.

1.4.3 Summary of sensory research on sous vide processed foods

Conclusions emerging from sensory research can be summarised, the numbers referring to examples in Appendix B:-

- There are few statistically significant differences in texture, aroma, flavour and appearance between chilled and frozen sous vide foods [4, 8, 23].
- There are few consistent differences between conventionally and sous vide processed foods [2, 3, 12].
- Heating to a higher end point temperature increases toughness of meats [11, 37].
- Flavour is intensified but the effect decreases with time in storage [29].
- Shelf-life is increased by the sous vide process [15, 19, 40].
- Higher processing temperatures are needed for acceptable texture in vegetables [50].

Apart from these points, general conclusions from the considerable amount of research on sensory aspects are difficult, some reasons for this being as follows:-

- Experiments have been designed to determine sensory changes caused by:-
  i) different storage temperatures and times [2, 15, 19, 29],
  ii) different cooking times and temperatures [11, 16, 29, 31, 55],
  or made comparisons between:-
  iii) sous vide and conventionally cooked versions of the same food [1, 5, 21, 25, 46],
  iv) versions of the same dish produced by several foodservice systems [22, 30, 34, 57].
- Some experiments have used recommended heat treatments which may be inherently too severe [43].
- Different statistical tests and sensory evaluation techniques have been used, making comparison difficult e.g. using different scales and attributes [5, 9, 12, 17, 31, 39, 51, 53].
- Inconsistent results between trained and untrained assessors [19].
- Many experiments may have problems of reproducibility when making comparisons e.g. repeated production of a freshly processed product to compare with a stored product [17, 19, 58].
- Results could often be specific for the piece of equipment used [53].
- Results are often product specific [12, 21].

The number of products manufactured commercially or for use in-house is vast: Pralus (1985) gave about 130 recipes and commercial producers commonly have 50 different products which vary according to the season so assessing all combinations of dish with variations in cooking times and temperatures, cooling times, storage temperatures and storage times would not be viable for the sensory analyst. As mentioned above, sensory analysts have used many techniques to assess the sensory quality of sous vide foods so the methods of sensory analysis must be briefly explained.

1.4.4 Methods of sensory analysis

Anecdotal comments on sous vide foods (Appendix A.1) have often involved emotional and psychological responses linked to many factors associated with the eating environment. In contrast, the scientific study of the sensory properties of foods by sensory analysts frequently disregards such responses preferring to rely on more objective observations and measurements made in a scientifically controlled environment.

Sensory analysis is now regarded as an objective science with improved training programmes for sensory assessors and a wider range of sensory tests and statistical techniques for data collection and analysis using sophisticated computer software packages. The sensory analyst can construct models of products, relate the results of laboratory tests to acceptability ratings from consumer studies and predict the effect of changes in a product's sensory profile on consumer acceptability. The most frequently-used methods (Lawless and Heymann 1998) include:-

- Consumer Acceptability Tests: Rating liking, preference or acceptability (hedonic), Ranking, Relative-to-ideal, Just-about-right scales for consumer studies.
- Difference Tests: Triangle, Paired Comparison, Duo-Trio, Ranking and Grouping for analytical location and identification of differences between products.
- Descriptive Tests: Conventional Profiling, Free Choice Profiling, Repertory Grid Method, Differential Profiling and Time-Intensity Measurements for analytical description of a product's sensory attributes and graphical display of results.

Many sources have provided outlines of how and when the various tests should be used as well as updates in the field of sensory analysis (e.g. Amerine *et al.* 1965; Piggott 1988; Thomson 1988; Meilgaard *et al.* 1991; MacFie and Thomson 1994; Meiselman and MacFie 1996; Lawless and Heymann 1998).

Difference tests would appear to be appropriate to discriminate between a dish cooked traditionally and the same dish cooked using the sous vide process and indeed have been (e.g. Light *et al.* 1988; Church 1990). They would not, however, enable the investigator to elucidate any differences or their magnitude on an absolute scale. Techniques for this could involve Quantitative Descriptive Analysis (QDA) [9]. QDA has been used for sous vide bolognaise (Armstrong 1996), sous vide chicken ballotine, vegetable rice and dauphinoise potatoes (Church 1990) as well as for more homogeneous foods such as beer (Meilgaard *et al.* 1979; Pierson 1980), wine (Vedel *et al.* 1972), whisky (Shortreed *et al.* 1981), strawberries (Shamaila *et al.* 1992), apple juice (Dürr 1979) and cider and perry (Williams 1975).

1.4.5 Understanding the balance between food safety and sensory quality.

It can be concluded that sensory analysis of sous vide foods has not clearly confirmed perceived sensory aspects (Appendix A.1). If heat treatments used in sensory studies have been severe, e.g. 10 minutes at 90°C or equivalent (Table 2), any high levels of sensory quality may well be reduced. Genigeorgis (1993) thought that the difference between sous vide products processed at 60°C for 12 minutes at the centre and those processed for a 6 decimal destruction of non-proteolytic *Clostridium botulinum*, was like 'day and night', suggesting that milder heat treatments combined with lactic acid salts could provide the necessary level of safety.

Tjomb (1990) discussed the balance between increased food safety risk at low pasteurisation temperatures (below 68°C) and the loss of sensory quality at high temperatures (over 80°C). He later contrasted the attitudes of chefs advising sous vide product manufacturers. For example, Georges Pralus considered sous vide as a cooking technique and extending shelf-life would reduce sensory quality. In contrast the food industry recommended a severe heat treatment, causing a texture deterioration which would not adversely affect products with sauce (Tjomb 1992).

Langley-Danysz (1992) has provided a useful diagram (Figure 8) credited to Barlet (1991) illustrating how sensory quality and levels of food safety vary according to the level of heat treatment. However, this diagram could be different for each recipe and possibly for each recipe component so a producer would need to undertake considerable research and development work to optimise the heat treatment for individual recipes in the wide range of available dishes.

Any producer of sous vide products has to decide the length of chilled shelf-life actually needed. Using a heat treatment to guarantee a shelf-life of, say, 21 days

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[9] Defined as:-'developing a list of descriptive terms, screening would-be assessors for possible membership of a panel, training judges, using sufficient replication so that the performance of the assessors, the effectiveness of descriptive terms, product differences and possible interaction effects may be isolated and evaluated by statistical analysis, and expressing the results graphically as well as numerically.' (Powers 1988).

may degrade the sensory and nutritional qualities unnecessarily if it would normally be used before 10 days of storage. Therefore selecting the desired shelf-life could eliminate much experimentation. Assessing all possible combinations in order to optimise sensory and nutritional qualities, while minimising microbiological risks over the period of chilled storage would be difficult to justify in terms of time and resources. The possible combinations would arise from the range of food products, possible heat treatments and storage times with replicates while allowing for inherent variation in the raw food materials.

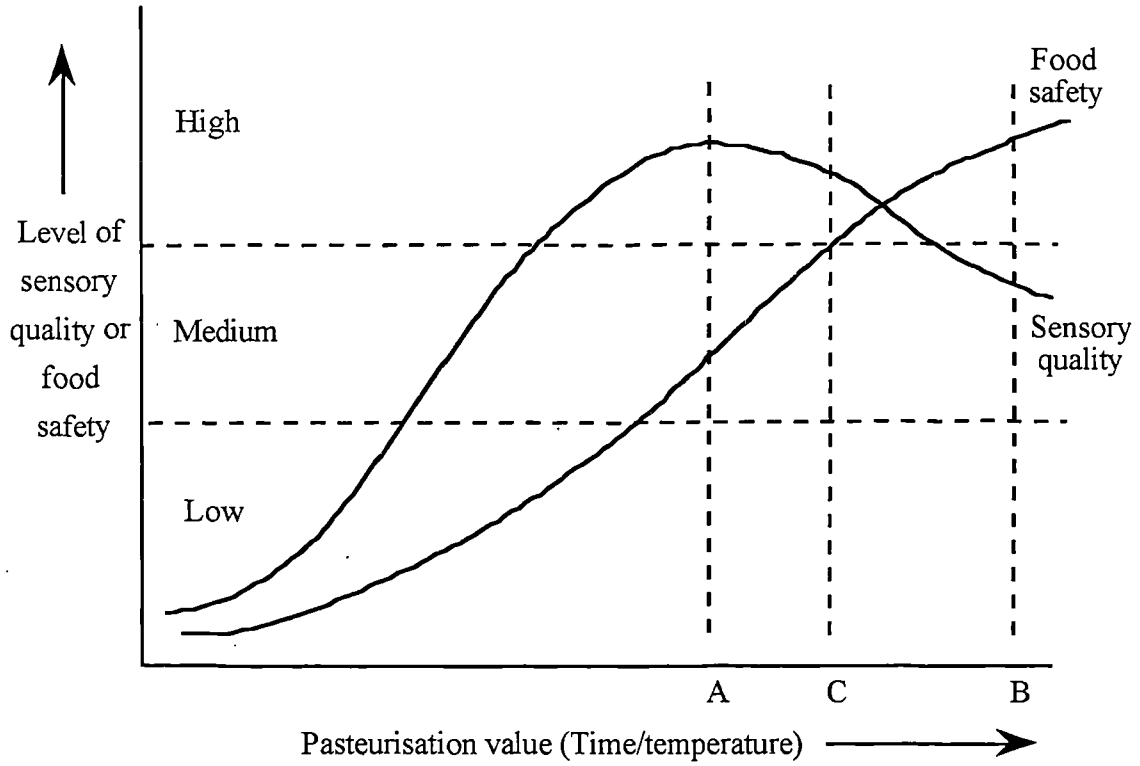

Figure 8. Optimising heat treatment for sensory quality and food safety of sous vide processed foods (A - high sensory quality/medium safety, B - medium sensory quality/high safety, C - optimum high sensory quality/high safety) adapted from Langley-Danysz (1992) and Barlet (1991).

Experimental design can reduce the number of experiments necessary but computer methods may be more efficient. Programs have been devised which, using data on meal ingredients and processing conditions, will model the changes in temperature, microbial load and texture over time (Schellekens *et al.* 1994). Programs using the neural network approach (Smith and Walter 1991; Peters *et al.* 1996) or expert systems (Linko 1998) have yet to be applied to chilled foods. Other methods are based on mathematical and statistical treatments: Xie *et al.* (1996) used fuzzy logic for unravelling contradictory information from assessors studying the sensory qualities of sous vide salmon, carrot and chicken products and determined

the product attribute which was most closely associated with the assessors' hedonic response.

1.4.6 The failure to agree on the sensory quality of sous vide foods.

The reasons for the apparent difference in opinion on the sensory excellence of sous vide products from chefs and restaurateurs (Appendix A.1) and from scientific studies (Appendix B) need to be clarified. If it is assumed that the heat treatment has not been too severe, the problem may be that what chefs have been expressing and what scientists have been measuring have of great interest to themselves but have not been relevant to the consumer. Chefs and scientists both focus on the food and its attributes. The chefs' subjective views of the flavours, odours and textures of sous vide foods (Appendix A.1), have been given while, perhaps, neglecting the effect of their own high presentational skills. On the other hand, by the usual scientific reductionist approach, the sensory analysts have extracted from sous vide foods only information they can measure with confidence using techniques mentioned earlier (section 1.4.4). Neither view necessarily describes the sensory qualities or pleasure during eating perceived by the consumer. These, in turn, are influenced by emotional and psychological responses linked to the many factors associated with the eating environment, especially in the restaurant (Pierson *et al.* 1995; Reeve *et al.* 1994), for example, decor (Bell *et al.* 1994) and effort (Meiselman *et al.* 1994).

The question then arises as to whether this type of emotional and psychological factor can be incorporated into an objective methodology for optimisation and evaluation of the quality of foods such as sous vide products. The usual method of gathering information from consumers through questioning by interview or simple questionnaires is feasible in a university training restaurant where customers are accustomed to participating in the training and evaluation processes (Reeve *et al.* 1994). Trying to incorporate questions to assess emotional aspects towards the meal or the mood of the consumer may be possible but limited by the short time available to maintain the respondent's interest.

The full value of minimal processing methods such as sous vide for enhancing the acceptability of foods will only be confirmed when sensory analysts and product development technologists can use more realistic techniques. These may take into account not only components of acceptability based on the sensory stimuli provided by foods but also how close the food comes to the individual's perception of the ideal in a normal eating situation. The next section explores the principles underlying existing models for measuring the acceptability and pleasure of food and how they might be modified.

1.5 Models for measuring the acceptability and pleasure of food

In order to understand how sensory analysis techniques can be developed into a model of food acceptability for products intended to provide a high degree of pleasure for the consumer, this section discusses:-

- the principles underlying the human perception of pleasure.
- the applicability of existing models of food acceptance and preference to the study of the pleasure of eating.
- the semantic differentials between consumers' opinions and sensory analysts' understanding.
- the development of scales used by scientists to measure this pleasure.
- how extrinsic factors might be incorporated into a practical model.

1.5.1 The human animal and pleasure

The 'pleasure principle', defined as the maximisation of pleasure and the minimisation of pain is widely regarded as a fundamental motive in human behaviour and survival (Cabanac 1985; Epstein 1993). Berlyne (1973) quotes Aristotle as writing 'where there is pain and pleasure, there is necessarily also desire' and' desire is an impulse towards what is pleasant'. Aristotle is also quoted (Solomon 1993) as defining emotion 'as that which leads one's condition to become so transformed that his judgement is affected, and which is accompanied by pleasure and pain'. In the nineteenth century Spencer linked pleasure to Darwin's theory of evolution as 'a correlative of actions conducive to its (the organism's) welfare' (Berlyne 1973; Solomon 1993). This non-psychological introspective view of pleasure or hedonism became entangled with ethics and petered out as a psychological theory of hedonism (Figure 9). Berlyne (1973) described the two remaining 'streams' as 'Behaviour' and Scaling' theory. Behaviour divides into three theories; reinforcement or reward; incentive value depending on expectation, and feedback. Scaling also divides into three theories; experimental aesthetics (subjective liking or preference); social attitudes (leading to Thurstone's (1927) and Likert's (1932) methods) and decision theory (based on utility). Berlyne (1973) considered that these psychological theories of human motivation accounted for behaviour in terms of consequences, to internal factors or external stimuli. Words relating to 'pleasure', 'satisfaction', etc. and their opposites are often used to describe the consequences of behaviour. The pleasure from an action corresponds closely to the internal motivational conditions preceding it and external stimuli signal when pleasure and reward are available.

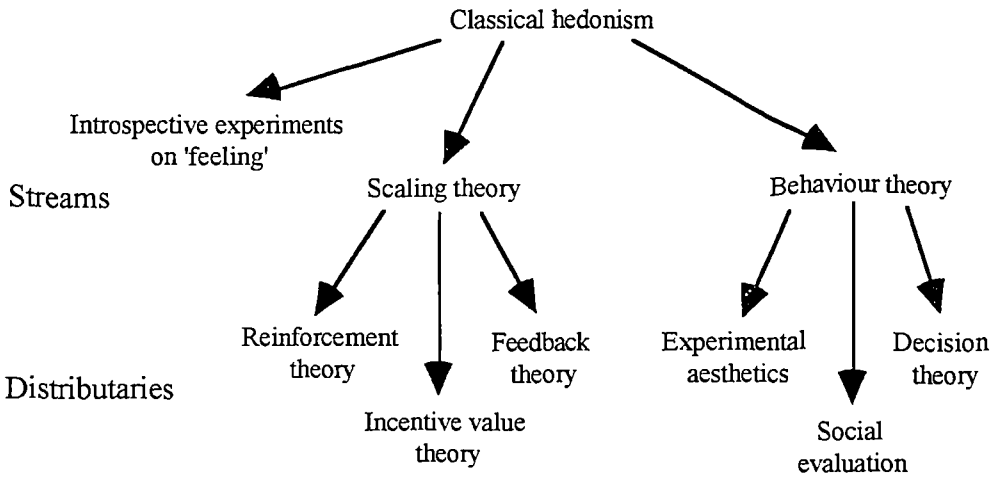

Figure 9. The Hedonistic delta - Offshoots of hedonism in psychological theory (Berlyne 1973).

Averill and More (1993) reviewed the relationship of systems of behaviour to happiness including one proposition that happiness consists of both 'a sum of momentary pleasures' and that these pleasures contribute to happiness only when 'informed by higher order sources'. These short-lived pleasures derived, for example, from reading a good book or eating a good meal may be 'integrated into more enduring states of happiness, e.g. with respect to work or family.'

Pleasure has been proposed as 'the end point of all animal behaviour' and 'a fact of neurology', not merely a feeling (Campbell 1973). He suggested pleasure could now be measured with appropriate instrumentation. His explanation of animal behaviour was that 'a single 'command' was given to the ancestral brain-computer: "Activate the pleasure areas !" ' through active seeking or self-stimulation of relevant areas of the brain through thought. Cabanac (1971) also argued that pleasure is not simply the result of an external stimulus but for thermal, olfactive and gustative stimuli depended on internal signals. He provided evidence for alliesthesia - the concept that the pleasure of sensations is dependent on the state of the body, e.g hunger perception and odour cues (Blackwell 1997). Young (1959) quoting experimental data from rats, argued that affective processes can be studied objectively because they can be defined in terms of 'sign, intensity and duration' across a hedonic continuum from 'distress' to 'delight' through 'indifference'. He distinguished between sensory and hedonic intensity in food acceptance studies and that palatability referred to the 'hedonic value' of a food dependent on sensory attributes as well as environment. He postulated that affective processes have an objective existence, intervening between stimulus and response in the motivating sense of arousing, sustaining, regulating, directing and organising neuro-behavioural patterns although the underlying physiological events were yet to be understood. Young thought this

would also apply to other hedonic areas such as sexual behaviour, play, manipulation, exploration and human action.

Cabanac (1979) proposed a three-dimensional model for sensation to include qualitative and quantitative dimensions with the hedonic continuum of Young (1959) (Figure 10). He considered that pleasure was a sign of a beneficial stimulus and displeasure a dangerous one thus motivating useful behaviours. However, Pfaffmann (1960) thought that gustatory stimulation could elicit and reinforce behaviour in its own right, pleasure for its own sake.

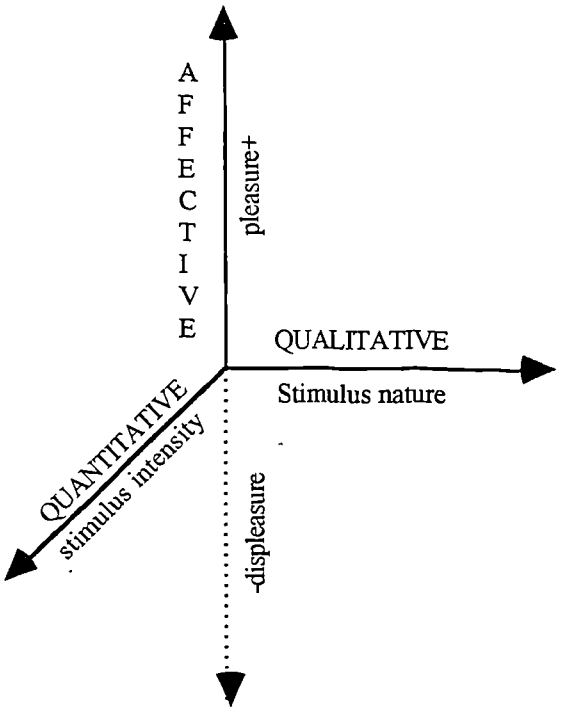

Figure 10. Tri-dimensional sensation from Cabanac (1979).

It can therefore be postulated that pleasure is fundamentally related to human motivational and physiological needs. These needs often focus on the eating of food so models of how these needs interact to explain and predict food acceptability have been devised.

1.5.2 The applicability of models incorporating factors affecting pleasure

Most models which measure pleasure incorporate psychological, physiological, sociological and contextual factors. From the previous section it can be seem that pleasure is deeply rooted as a human emotion affected by many psychological and physiological factors. In eating situations, the additional sociological effects on the individual, e.g. group and peer pressure, and contextual factors cannot be ignored (Meiselman 1996a). How these factors can influence behaviour needs to be considered when trying to measure and predict the ideal qualities of foods and so relate it to the degree of pleasure experienced by the individual.

The scientific approach to understanding the many interactions of these factors is to devise a model of food acceptance. However, the form of model is dependent on the viewpoint of the modeller. Cardello (1994) discussed the various viewpoints of researchers from different disciplines, e.g. physiology, cognitive psychology and behavioural psychology in formulating models.

Several food acceptance models summarised in Table 3 and shown in detail in Appendix C are based on either:-

- a sequential approach - showing the factors sequentially through the process of the consumer accepting food.
- an interaction approach - showing the interactions without detailing the mechanisms involved.
- listing the factors or
- using more generalised and wider models, e.g. motivational.

As there is much interconnection between these various factors, the following section discusses and illustrates the influence of some of the 'Human' and 'Situational' factors on food acceptability and hence perceived pleasure (Appendix C).

1.5.3 Human and situational factors influencing food acceptability

Associations gained from prior experience can have a strong influence on food preferences, for example, linked to specific emotions on certain occasions, or associations gained without experiencing a food (Lyman 1989). Repeated exposure can also develop a liking for innately unpalatable substances with exposure tending to dissipate fear of a new food (Pliner 1982; Rozin 1989).

Reference	Type	Factors included							
		Instru-mental	Food	Sens-ory	Physiologic al	Psych ologic al	Lear-ning	Socio-logica l	Situat-ional
Pilgrim 1957	Sequential		X	X	X		X		X
Harper 1981	Interaction (neural mechanism)	X	X	X	X		X		
Khan 1981	Interaction		X	X	X		X	X	X
Randall & Sanjur 1981	List		X	X		X			X
Land 1983	Sequential		X	X			X	X	X
Shepherd 1985	Sequential		X	X	X	X	X	X	
Land 1988	List		X		X	X			
Piggott 1994	Sequential		X	X					X
Cardello 1994	Sequential + Feedback		X	X	X	X	X	X	X
Cardello 1996	Sequential		X	X			X		

Table 3. Summary of factors included in food acceptance models.

An individual's culture or ethnic group may be the best predictor of that individual's food habits and preferences (Rozin 1996). Different cultural attitudes exist towards food, for example, the French thinking of food in terms of cuisine and pleasure and Americans in terms of nutritional content and health risks (Martens 1995).

Expectations arising from intentional or unintentional cues sensed consciously or unconsciously can stimulate responses learned from previous experience, e.g. odour (Blackwell and Pierson 1996; Blackwell 1997). Information can be manipulated by the food product marketer or the restaurant owner using packaging images, menu design and wording, advertising, the chef's reputation, etc. to raise expectations for food acceptability. Some examples are names given to the food product: labelling altering consumers' expectations of some attributes of low-fat products compared to the regular-fat versions (Tuorila *et al.* 1994; Kähkönen and Tuorila 1998): pure suggestion influencing the acceptance of an unfamiliar beverage (Zellner *et al.* 1988): the environment changing expected food acceptability in hospitals, restaurants, etc. (Cardello 1994; Cardello *et al.* 1996), student refectory or restaurants (Meiselman 1996b). Sensory characteristics or the level of acceptability may be confirmed by expectations (Anderson 1973; Cardello 1994; Raats *et al.* 1995), but disconfirmed expectations of a novel food could adversely affect acceptability (Cardello and Sawyer 1992). Consumer expectations are seen as a key

factor in the influence of the packaging and the associated marketing and advertising which make up the concept and image of a branded food product (Meiselman 1996a). Another concept linked to expectations is appropriateness which introduces the individual's associations with location, mood and social situation (Schutz (1988a, b; 1994b; Cardello and Schutz 1996).

The human body incorporates mechanisms to satisfy its biological needs, for example, cravings for chocolate or fish. Foods may be eaten for their 'powerful hedonic effects' on mood and to increase pleasure and relieve boredom (Rogers *et al.* 1992). Other mechanisms are hunger and satiety; hunger the motivation to eat and satiety the maintenance of inhibition of further eating with satiation being the process of moving from hunger to satiety (Blundell *et al.* 1988).

Individual consumers can also have varying attitudes towards foods; some may limit themselves to a restricted range compared to others. Variety seeking has been measured using a list of statements with 5 point Likert agree/disagree attitude scales (Van Trijp and Steenkamp 1992) and the opposite, food neophobia, using 5 positively and 5 negatively worded statements with a 7 point Likert disagree/agree scale (Pliner and Hobden 1992; Pliner *et al.* 1998).

Personal values of consumers can be judged through measuring attitudes: the Fishbein and Ajzen (1975) model of reasoned action (Figure 11) has been used by Shepherd (1988) to predict the use of table salt and low-fat milk. Shepherd (1994) later used 'the theory of planned behaviour' (Ajzen 1988) to explain consumers' intentions to buy organic vegetables. Others have studied milk, additives and genetic engineering (Raats *et al* 1995; Shepherd and Raats 1996).

Consumer income can affect spending on eating in restaurants or workplace canteens: Meiselman (1996b) showed that manipulation of price can change food selection, e.g. vegetables.

Mood can influence food choice: Lyman (1982a, b; 1989) asked students to report feelings after eating food and food preferences when they imagined experiencing various emotions. Healthful foods were preferred during positive emotions and junk food during negative emotions. Overall, initial moods were enhanced by the associations of the food eaten; those with pleasant associations enhanced an initial positive mood, those with unpleasant associations worsened an initial negative mood (Lyman 1989).

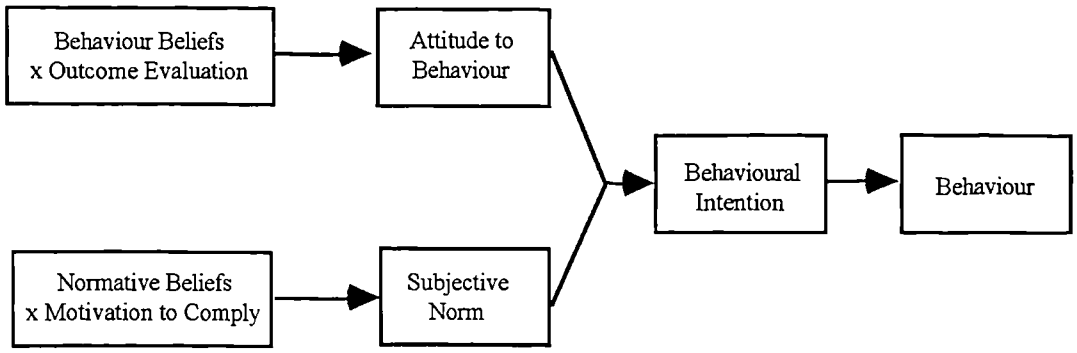

Figure 11. Components of the Fishbein and Ajzen attitudes model (Shepherd 1988).

The wide use of manipulation of the physical environment by restaurateurs through decor, layout, style of service and type of information, etc., has received relatively little attention (Meiselman 1992, 1996a). Some studies changed restaurant decor to fit in with an Italian theme which increased perceived ethnicity but not food palatability (Bell *et al.* (1994): increasing the effort required to purchase a snack item reduced their normal selection rate and increased selection of an alternative item (Meiselman *et al.* 1994): pre-prepared foods tended to show higher hedonic and appropriateness ratings in a restaurant than in a student refectory (Meiselman 1996b): meal items priced individually compared to a set meal price increased the selection of vegetables for the set meal although hedonic ratings did not change (Meiselman 1996b).

The social environment also has effects: meal size and duration increased as numbers increased: meals eaten alone were smaller than those eaten with others: food acceptance was correlated with food intake when meals were eaten with others: and opinions of authority figures, e.g. army sergeants, had a significant influence on how much their subordinates ate and liked the food (Meiselman 1996a).

Attributes on the restaurant table such as topography, neatness, quantity, harmony and emphasis can adversely affect the acceptability of the meal if not appropriate, whatever the sensory quality of single meal components (Eckstein 1982). The acceptability of one food could be partially determined by which foods were also eaten, particularly important for prepared packaged meals (Meiselman 1996a). In the free-choice environment, the main dish showed the largest effect on overall meal acceptability (Hedderley and Meiselman 1995). However, to understand the effect of all these factors on the pleasure of eating entails defining the terms generally used to describe pleasure.

1.5.4 Semantic differences between consumers and sensory analysts

Several words connected with food and pleasure can be used by consumers. Sous vide foods have often been described using such terms as 'perfection', etc. However, when assessors are judging samples of a similar high quality, their vocabulary may become inadequate (McBride 1990).

The concept of perfection with regard to food could comprise several levels contributing towards the overall level of pleasure using words such as 'acceptability' 'preference' and 'liking' - the hedonic response. These terms could be considered as independent variables; a food could be acceptable but not necessarily liked or preferred; a food may be preferred over another but both may be disliked or unacceptable. Pierson (1997) made the following distinction:-

> 'Acceptability may be regarded as a pre-defined level of quality .....
> Preference may be considered to be based on comparative levels of like and dislike for a series of products. Consider two products, both of which may be acceptable to the individual consumer since they satisfy their requirements, but one is liked more than the other and hence is preferred. Acceptability may be defined as the state or quality of food which makes it agreeable, satisfactory, worth accepting and welcome.'

The use of these terms will also be modified by consumer attitudes themselves influenced by many factors discussed earlier (section 1.5.3).

In food research, Meiselman *et al.* (1988) noted that 'acceptance' has been defined by Amerine *et al.* (1965) as:-

> '1) an experience, or feature of experience, characterised by a positive (approach in a pleasant) attitude.
> 2) Actual utilization (purchase, eating). May be measured by preference or liking for specific food item. The two definitions are often highly correlated, but they are not necessarily the same.'

and that Peryam *et al.* (1960) defined acceptability:-

> 'in terms of consumption and morale - acceptable food is one that will be eaten and eaten with pleasure and satisfaction'.

This definition had developed from Pilgrim (1957) who suggested that:-

> 'the criterion of food acceptance should be specified as "consumption with pleasure" - we might say, "the nutrition of body and soul." '.

These definitions emphasised the link between acceptance and consumption now missing in a recent definition by Stone and Sidel (1993):-

> 'By acceptance testing we mean measuring liking or preference for a product. Preference is that expression of appeal of one product versus another.'

Land (1988) quoted two standard definitions of acceptance:-

'an hedonic assessment of adequacy within a specified range' (BS 5098, BSI 1975) and 'the act of a given individual or population of favourably consuming a product' (International Standard 5492).

but considered they did not provide a basis for measurement, only for classification - acceptable or not acceptable. He proposed that:-

'The acceptability of a product is the level of continued purchase or consumption by a specified population.'

This emphasised the need to be specific for a product and population, to use a range of levels of continued behaviour and to imply purchase or consumption. This definition agrees with Meiselman *et al.* (1988) in the inclusion of consumption as a necessary factor for measuring food acceptability but presumably takes for granted that the food is liked.

If the terms 'acceptability' and 'liking' are considered at the positive extreme of their meaning, the overall concept may be thought of as 'pleasure' defined as 'a state or feeling of happiness or satisfaction', 'a source of happiness or satisfaction', 'enjoyment' or 'satisfaction'.

The term 'pleasure' has many synonyms [10], the word itself being the most general and the least forceful term. The methods for scientists to obtain information from humans on foods which can measure the degree of pleasure have usually made use of scales.

1.5.5 The development of scales to describe pleasure

The overlapping areas of psychology and physics aiming to explain the link between a physical stimulus or event and the sensation perceived and therefore the basis for any scales used, is known as psychophysics. Its roots lie in work by Weber and Fechner (1860) who suggested that 'an increment to a stimulus becomes just noticeable when it reaches some fixed percentage of the original stimulus.' (Stevens 1974).

or $$\Delta\psi = k\left(\frac{\Delta\phi}{\phi}\right) \qquad [1]$$

where $\Delta\psi$ = the just noticeable difference in the sensation, y

k = constant

$\Delta\phi$ = increase in stimulus

ϕ = magnitude of original stimulus

Integration of [1] gives the 'Weber-Fechner Law':-

---

[10] 'delight' suggests a keener and evident, often fleeting pleasure, 'joy' suggests a deeper, longer lasting 'delight' often with spiritual connotations, 'delectation' and 'enjoyment' both stress the reaction to pleasure as opposed to the feeling itself, the first stressing the provision of entertainment and the second, conscious savouring of what pleases someone.

$$\psi = k \log \phi \qquad [2]$$

This law was challenged by Plateau (1872) who thought that the subjective ratios remained constant not the subjective differences. The idea was defiantly dismissed by Fechner (1877). Stevens (1957, 1960, 1961, 1974) later resumed the challenge to propose that the connection between sensation and stimulus was governed by a power law not a logarithmic law.

$$\psi = k\phi^n \qquad [3]$$

where ψ = magnitude of the sensation

k = constant

ϕ = magnitude of original stimulus

n = exponent

He studied a wide range of stimuli such as loudness, brightness, smell, taste, temperature, etc., producing exponent values (n) from 0.33 (brightness) to 3.5 (electric shock) (Stevens 1960, 1974).

Jones (1974) and Lawless and Heymann (1998) have reviewed the history and development of psychophysics including Thurstone (1927) whose 'Law of Comparative Judgement' has also been influential in psychophysics. This proposed that the discriminal processes (sensations) produced by any repeated stimulus have a normal distribution and so the unit of standard deviation can be used 'as a unit of measurement for the psychological continuum under investigation.'

Words used in scales can influence how the stimulus is perceived and marked on the scale. Therefore semantics become essential to determine how words are understood by a wide range of assessors making assessments of food attributes. Mosier (1940) requested subjects to assign words to a common scale which were given scale values after a normality check (Thurstone 1927). Other work (Mosier 1941) showed words such as 'acceptable', 'important' and 'indifferent' exhibited bimodal responses. Others, such as 'unnecessary', showed a 'precipice' effect where instead of a distribution declining normally, it stopped suddenly. This was thought to be due to an 'end-effect', the subject assuming a perceived boundary between two scales. Later work by Jones *et al.* (1955) and Jones and Thurstone (1955), obtaining scale values for words, led to the widely-used hedonic scale (Peryam and Pilgrim 1957) which is discussed later.

For the highest external validity, the ideal point for acceptance of a particular attribute or overall liking should come from consumer data (Schutz 1988b) ideally based on food purchasing or consumption (Meiselman 1992). These methods can be impractical and time-consuming so often the pragmatic way is to use 'direct psychophysical scaling of the hedonic element of foods' (Cardello 1996). The most widely-used form of this method is the hedonic scale (Peryam and Pilgrim 1957).

Other scales frequently used in food acceptability studies include the magnitude estimation scale (Moskowitz 1980, 1982), Relative-to-ideal scale (Booth *et al.* 1983), Just-about-right scale (Stone and Sidel 1993), Likert Scale for measuring attitude (Likert 1932) and the Intensity scale (Stone and Sidel 1993). The food action rating scale (Schutz 1965) and R-index values (O'Mahony 1979; Vié *et al.* 1991) have also been used.

1.5.5 a) The hedonic scale

The hedonic response is basic to the pleasure of eating. Cardello (1996) thought it dissimilar to a sensory response because the same physical stimulus can produce pleasure and displeasure in different individuals. The relationship between sensory stimulus and hedonic response can be illustrated by the Wundt Curve (Figure 12) (Wundt 1902) originally proposed in 1874. The hedonic response increases with sensory intensity up to a maximum point, the bliss point, but declines as the sensory intensity increases further past a neutral point to eventually give a negative response. Cardello (1996) contrasted the shape of this curve with that between the perceived sensory intensity and the physical intensity of the stimulus itself which would be a monotonically increasing function such as a power law.

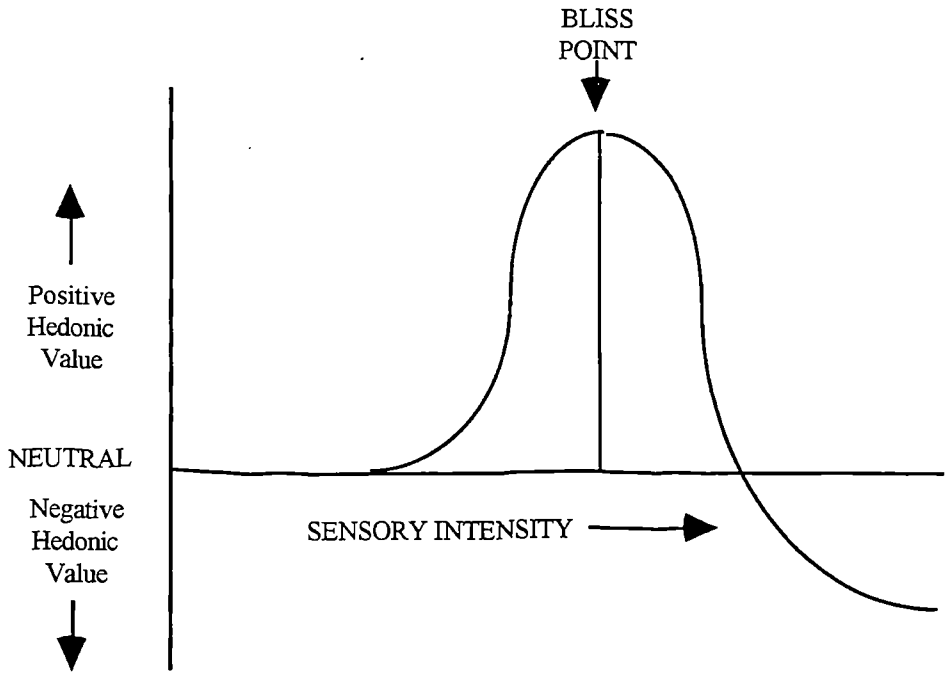

Figure 12. Wundt Curve - Relationship between sensory intensity and hedonic response (Wundt 1902).

The hedonic scale (Figure 13) was developed by Peryam and Pilgrim (1957) and has been used extensively. Some workers have questioned how the average scores collected from groups of assessors relate to the success of the product in an

eating environment (Bell and Meiselman 1995). Pilgrim (1957) realised this problem suggesting the scale did not get at 'the basis of the differences in preference that arise from processing, storage or other experimental variables.'

The hedonic variable can be measured on a multi-point scale from dislike to like using balanced modifiers (extremely, slightly, etc.), for example, as a 7-point scale (Figure 13), although a 9-point scale is often used.

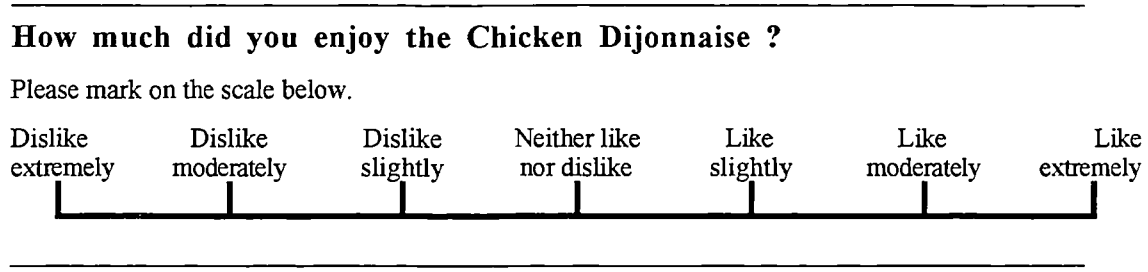

Figure 13. An example of an hedonic scale.

If the scale length is set at a standard 100 or 150 mm, then responses can be measured from the left-hand side or a frequency distribution can be collated using each category. Measuring to the nearest millimetre does not imply that the assessors are using a 100 or 150 point scale; a scale of 7 ± 2 points has been quoted as the number which can be used by an untrained assessor without confusion (Miller 1956). The scale has also been used for assessing the liking of particular food attributes and overall liking, using linear regression to determine which attribute best predicts overall food acceptability (Cardello 1996).

1.5.5 b) The magnitude estimation scale

Using this scale, assessors select their own numbers for rating how much they like or dislike a food (Moskowitz 1980; 1982). The first food presented is given an arbitrary score with the second food being scored compared to the first, either higher for liking more, or lower for liking less, etc. Scores from different consumers are compared by normalisation.

1.5.5 c) Relative-to-ideal scale

The relative-to-ideal scale aims to measure the 'perfect' or 'ideal' point for a single attribute (Figure 14). Examples of its use are for determining: the ideal salt concentration in bread and tomato soup (Booth *et al.* 1983; Shepherd *et al.* 1984; Griffiths *et al.* 1984): consumer sweetness preferences in a lime, chocolate drinks and tomato soup (Conner *et al.* 1986, Conner *et al.* 1988) and plain yoghurt (Daillant and Issanchou 1991): salt and creamer concentrations in chicken cup-a-soup (Booth and

Conner 1990): and butter, saltiness and sweetness intensities in Danish cookies (Poulsen *et al.* 1996).

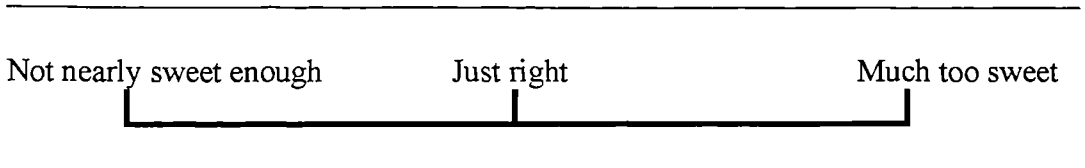

Figure 14. The relative-to-ideal scale: an example for sweetness.

1.5.5 d) Just-about-right scale

A similar scale to Relative-to-ideal is the Just-about-right scale (Figure 15) (Stone and Sidel 1993). They discussed how assessors react to attribute intensity and preference in one single response with a preponderance of judgements placed in the centre of the scale and suggest methods for statistical analysis using the Chi-squared test etc. Baldry (1981) also used this scale for assessing the sweetness and firmness of mangoes. A variation of this scale is included in the SQS (Sensory Quality System) for use in food manufacture (Beckley and Kroll 1996). This comprises a quality score including scoring flavour and appearance attributes on a 4 point scale ('Not nearly enough', 'Not enough', 'Too much', 'Much too much').

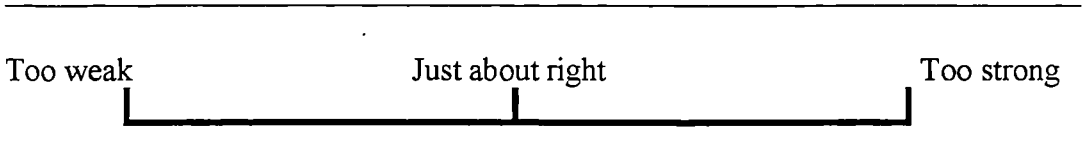

Figure 15. Just-about-right scale: an example for aroma.

1.5.5 e) Likert Scale for measuring attitude

The Likert Scale can be used to clarify attitudes towards food products by giving respondents a statement and asking them to show their level of agreement, by placing a mark or code number along the line (Likert 1932) (Figure 16) :-

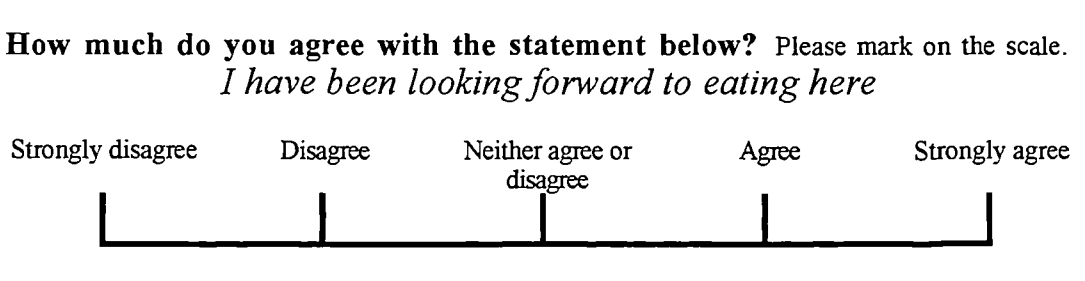

Figure 16. An example of a Likert scale.

1.5.5 f) Intensity scale

Intensity scales are the basis for sensory profiling where attributes are rated from absent to extreme. Rappoport *et al.* (1993) defining pleasure as 'All forms of sensory, social, emotional or aesthetic pleasure', asked assessors to estimate the pleasure value of a list of 35 meals and snacks, using a 5 point scale from 'none', 'slight', 'moderate', 'high', to 'very high'.

1.5.6 Particular advantages and disadvantages of scales

The problems in using the hedonic scale have long been discussed; the assumption of linearity or equal intervals, under-utilisation of the end points and use of the neutral point (Land and Shepherd 1988; Cardello 1996).

The linearity assumption was tested with subjects asked to place words meaning various degrees of like or dislike, on a common 9 point scale from 'greatest dislike' to 'greatest like' via 'neither like nor dislike' (Jones and Thurstone 1955; Jones *et al.* 1955). They showed that phrases at extremes of the scales were more ambiguous than phrases near the middle of the scale. This was thought to be due to the modifiers normally having positive connotations, e.g. 'highly' being used with negative terms. However it was concluded that the slight departures from linearity were not serious. Cloninger *et al.* (1976) tested scales from 5 to 15 points using normalisation, finding that 5 point scale intervals were nearly equal but 9 and 15 point showed a 'central' tendency, i.e.. lower use of the extremes.

Harper (1981) advised caution when using the 9 point hedonic scale because assigning an extreme value which is then superseded means there is no space further than the extremes to place another mark. For foods with high sensory qualities, many assessors may only use the extreme end of the hedonic scale so magnitude estimation may overcome this problem.

Moskowitz (1980) compared ratings from the hedonic and magnitude estimation scales. The magnitude estimation values exhibited unequal intervals, with the 'like' end of the scale having larger intervals than the 'dislike' end. Moskowitz (1980) considered the magnitude estimation scale as being more sensitive and less biased at the extremes of scales allowing better statistical analysis compared to the 9 point hedonic scale although both scales can be used to complement each other in terms of measuring food acceptance (Moskowitz and Sidel 1971). Pearce *et al.* (1986) compared two forms of magnitude estimation scaling and one a category based hedonic scale using liking for the feel of various fabrics as food was not feasible for the 23 laboratories and 553 assessors used. No scale showed any superiority in reliability, precision or discrimination. However, others have considered magnitude estimation to have no great merits (Birnbaum 1982; Stone and Sidel 1993).

The Relative-to-ideal and Just-about-right scales offer assessors the opportunity to make assessments based on their personal ideal value of liking or preference. Shepherd *et al.* (1984) using tomato soup concluded that the relative-to-ideal scale offered the advantage of giving a continuous measure for the ideal point compared with the hedonic scale. The scale has also been used to study the wide variation in individuals' ideal points, where averaging data from groups to provide an overall ideal point loses information (Booth and Blair 1988; Booth and Conner 1990; Conner 1994).

However, the effective use of these scales in determining the level of consumer acceptability and hence the success of a food product will depend on their perceived relevance to foods eaten in real situations as affected by the factors discussed earlier in section 1.5.3.

1.5.7 Linking measured sensory and affective variables to consumer acceptance.

The success of new food products depends on satisfying consumers' needs in many ways. Despite product developers using the highest standards and premium ingredients to produce the highest quality product, most new food products fail to make an impact on the market. Sidel and Stone (1993) thought that often the manufacturers' view was that consumers were 'unaware of what was best for them'. Manufacturers were recommended to assess products before market launch more thoroughly especially to understand consumers' discriminative, descriptive and affective aspects (Sidel and Stone 1993).

In attempting to understand these aspects, with constraints on time, money and practicability, manufacturers will have to compromise between producing foods with appeal to individual consumers or to larger groups. Consequently, problems in making decisions based on grouped or individual data and their attendant differences in data gathering techniques will arise. These problems are exacerbated by three common choices for sources of data:-

- Individual consumers or groups of consumers.
- Simple foods or complex multi-component foods.
- Convenient artificial environments or realistic eating environments.

1.5.7 a) Individual consumers compared to groups of consumers.

Booth (1981) noted that acceptability, palatability and liking are dynamic characteristics of food, changing with the individual's psychological states. These could be determined by psychometric tests but would be impracticable, involving obtaining too many responses. Booth (1981) proposed reducing the number of attitudes to be measured, to four motivational measures of acceptability from one extreme to another; (nice/nasty, good for you/bad for you, convenient to

use/inconvenient, suitable/unsuitable) and two more neutral measures depending on the circumstances (economical/expensive, usual/novel). Booth (1990) also questioned the existence of a 'perfect' product combining attributes to please every consumer. He considered grouping data as an assumption for simplifying data gathering and analysis. If an ideal point was found, this set of conditions may apply only to a small group of consumers because of the many other factors influencing consumer choice. In other words, the ideal point as shown by an inverted U-shape emerging from grouped data, was just an artefact of mathematical manipulation (Booth 1990; Conner and Booth 1992; MacFie and Hedderley 1993). Conner (1994) stated that the relationship between acceptability and an attribute of a single food constituent varied in units of equal discrimination showing the mental mechanism in operation. Thus an inverted U-shaped curve was claimed to indicate poorly designed testing procedures or 'premature aggregation' of individual responses. This shape could also reveal underlying traits, e.g. bimodality - strong likers and dislikers of a product (Cardello 1996). This has been shown to apply to beer (Pierson 1980).

The work of Booth and co-workers has often emphasised this point. They considered an individual's response to a particular influence e.g. sensory stimulus, image, price and usage of the food product on brand choice, would form an isosceles triangle, an inverted V-shape, known as the Appetite or Acceptance triangle (Booth and Blair 1988; Booth and Conner 1990; Conner 1994). However food acceptance must realistically depend on several stimuli acting simultaneously on the consumer, not just one.

1.5.7 b) Simple foods compared to complex multi-component foods.

Measuring subjective or affective variables from multi-component foods is difficult. There can be such a range of sensory characteristics of several components that the interactions can have critical effects on consumer perception (Cardello 1996). Meiselman (1994) has questioned whether it would ever be possible to 'deal with the sensory complexity of a multi-component meal' and thought that subjective expectations by consumers may have more influence than the sensory characteristics.

The interaction of taste mixtures reviewed by Cardello (1996) who gave examples of adaptation further highlights the problems of evaluating multi-component foods.

1.5.7 c) Convenient artificial environments compared to realistic eating environments.

This question has been widely discussed: Booth (1992), Kissileff (1992), Mela *et al.* (1992), Pliner (1992), Rolls and Shide (1992) and Tuorila and Lähteenmäki (1992) arguing with Meiselman (1992) about the merits of using

laboratories or real eating environments to study aspects of human eating behaviour. Earlier, Schutz (1988b) related the factors of the type of respondent, measurement procedure and type of stimulus to the level of external validity for food acceptance evaluation (Figure 17). For example, high external validity is produced by measuring the consumption of real foods on random consumers and low external validity by measuring the hedonic rating of pure substances using expert panels.

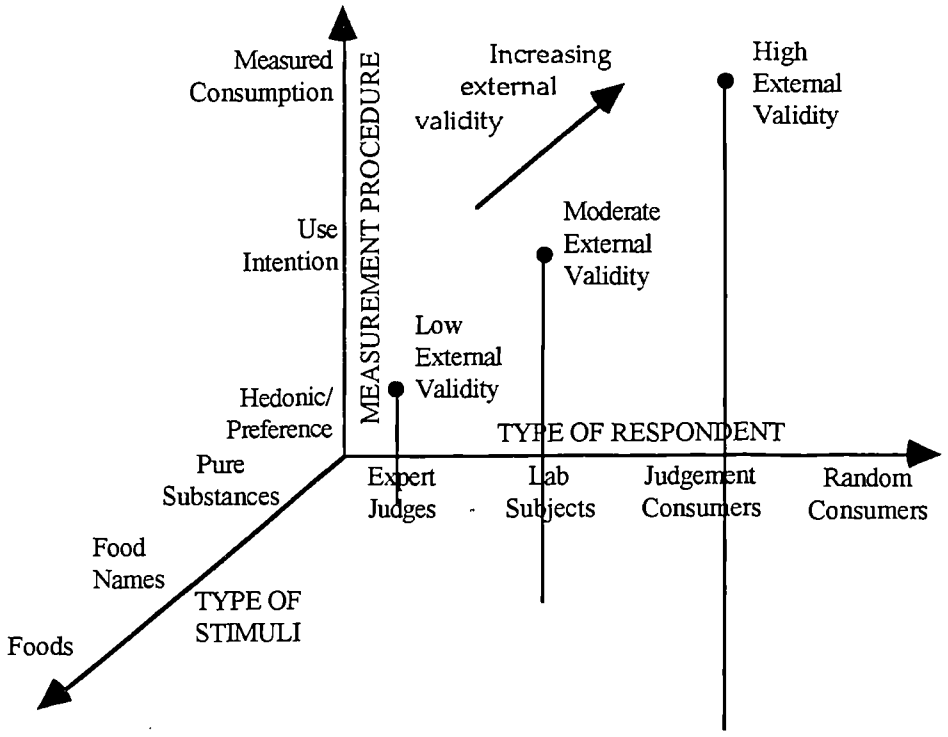

Figure 17. Food acceptance external validity evaluation dimensions, adapted from Schutz (1988b).

As consumers become more sophisticated, as noted in section 1.2, it becomes more difficult for food manufacturers to know what consumers consider to be the best quality. Stone *et al.* (1991) considered two kinds of information were needed: descriptive sensory data from a trained panel and preference data from consumers, starting with consumers' rather than the manufacturers' requirements. Lawless and Claassen (1993) agreed, calling it the 'central dogma' and stating that trained panels should not be asked questions on acceptability and consumer panels questions on specific attributes. They suggested that researchers should consider the trade-off between the precision of trained panels and the validity of consumer panels. In contrast, Moskowitz (1997) found that consumers were capable of tracking changes in product formula variables and sensory attributes of ready-to-eat cereals almost as well as the expert panels. Using fruit juices, Molnár *et al.* (1992) also found that expert and consumer panels agreed well in ranking according to an overall quality

score based on appearance, colour, smell and flavour. However, Cardello and Schutz (1996) thought that the circumstances of consumer tests, often conducted during the day in shopping malls, could make assessments of consumer liking invalid, for example, due to the unrealistic times of consumption for certain foods or if the prevailing climate is not appropriate. For the same products, a trained panel might find differences whereas the untrained panel might not (O'Mahony 1995). If the untrained panel found differences, it is assumed that the normal consumer would also find them.

The variability in consumer responses has led to a variety of mathematical techniques to process data in order to produce useful information for the sensory scientist.

1.5.8 Mathematical techniques used for food acceptance research

Several mathematical techniques can be used to analyse data based on the models described earlier, the most relevant being factor analysis and regression modelling, e.g. least-squares regression, partial least-squares regression, Procrustes analysis, multi-dimensional scaling, etc. using raw data or data which has been rationalised by principal components analysis and other multivariate techniques (MacFie and Thomson 1988; Williams 1988; 1994b; Hair *et al.* 1995).

One simple concept to bring many types of attribute together is desirability values. An attribute level considered just acceptable is assigned a desirability value of zero and a fully acceptable level is given a value of one. Various transformations allow linear, non-linear and bell-shaped relationships between attribute level and desirability value (Harrington 1965). Desirability values from different attributes can then be combined to give an overall Desirability Score using the geometric mean (Derringer and Suich 1980). Examples of its use include optimising the quality of wine (Clementi *et al.* 1990) and the flavour of Provolone cheese (Bertuccioli and Rosi 1994).

Other optimisation techniques include: neural networks for predicting sensory attributes of beverages from composition (Bardot *et al.* 1994) and Taguchi methods for optimising product characteristics using a target value and relating this to scales similar to the Just-about-right and hedonic scales (Gacula 1993).

1.5.9 Choice of methods for assessing the quality of sous vide products

Section 1.4 has outlined the diversity of research work on sous vide foods and the use of a wide range of methods for sensory evaluation of these products. However, the outcome of these studies has been relatively inconclusive. McBride (1990) suggested that when a food is 'highly acceptable - consumers find themselves limited to variants of hedonic terminology, such as 'superb', 'well-balanced' or 'just

right'. It is literally, too good for words'. This view reinforces the tentative conclusion that the sensory assessment methods used for sous vide foods have not been measuring what the consumer might actually be experiencing or at best, only a small subset of those factors. McBride (1990) also suggested that the next stage for future development of sensory evaluation should construct theories which show how hedonics drive food acceptance.

1.6 Aims and objectives of this research

1.6.1 Aims

- To determine whether claims of sensory superiority of sous vide products are justified.
- To question the validity of a single linear scale to assess the acceptability of food.
- To determine the relative importance of intrinsic and extrinsic factors affecting food acceptability.

1.6.2 Objectives

- To determine whether consumers can discriminate between products cooked conventionally and those processed by the sous vide method.
- To measure the ideal qualities of food cooked conventionally and processed by the sous vide process both eaten in an ecologically valid environment [11].
- To determine how individual consumer characteristics influence their perception of high quality foods.
- To develop a model predicting the importance of the pleasure of eating in an ecologically valid environment and to compare this pleasure with that experienced in other human activities.

[11] The term 'ecological validity', used in cognitive psychology (Eysenck and Keane 1995) is discussed as the 'realistic eating environment' in section 1.5.7 c.

2 Empirical Investigations

In order to meet the objectives of the research, experiments were designed and conducted in a sequential series. To maximise clarity, the work is presented as a series of experiments with results discussed individually and specific conclusions drawn. The statistical tests used are listed and explained in Appendix F.

Section 2.1 To determine whether consumers can discriminate between products cooked conventionally and those processed by the sous vide method.

Section 2.2 To measure the ideal qualities of food cooked conventionally and processed by the sous vide method both eaten in an ecologically valid environment.

Section 2.3 To determine how individual consumer characteristics influence their perception of high quality foods, to develop a model predicting the importance of the pleasure of eating in an ecologically valid environment and to compare this pleasure with that experienced in other human activities.

2.1 Experiment 1 - To determine whether consumers can discriminate between conventionally and sous vide cooked foods.

2.1.1 Introduction

The objective of the first experiment was to determine whether untrained assessors could perceive any sensory differences between the same dish prepared by traditional methods and by the sous vide process. These experiments were conducted in sensory booths under controlled laboratory conditions.

2.1.2 Materials and methods

The dish selected for this part of the experimentation was Chicken in Red Wine sauce; the selection being based on the product's commercial importance in the U.K. and U.S.A, and its simplicity of preparation.

Details of the recipe and preparation of the sauce are in Appendix D.1-a. Fresh chicken breasts were purchased from a local butcher, trimmed and cut into approximately 1 cm cubes. Those for sous vide preparation were placed in a laminated plastic bag, 200 mm wide by 300 mm long (Cryovac Z101 [12]); the average weight per bag being 1.6 kg. After adding 450 ml of cooled sauce, the bags were

[12] W.R. Grace, Northdale House, North Circular Road, London, U.K.

vacuum-sealed using a Multivac [13] vacuum packaging machine. The final pack thickness was 18.5 mm. The packs were stored for 24 hours at 3 °C to ensure a constant initial temperature and then cooked for 60 minutes at 80 °C to an internal temperature of 75 °C in a combination steam oven (Rational Combi CM10 [14]). The packs for refrigerated storage were cooled in iced water at 2 °C to reach an internal temperature of 7 °C within 50 minutes and stored at 3 °C for up to 12 days. Reheating was performed by placing the packs in hot water at 85 ° to 90 °C until the contents reached 80 °C. Temperatures were measured using a Kane May [15] electronic thermometer accurate to ± 0.5 °C. The conventionally prepared dishes were prepared by simmering the chicken pieces in sauce for 45 minutes in an open pan over a gas hob.

The untrained assessors had no prior knowledge of the research topic and procedures and were regular consumers of chicken. The Duo-Trio Test was used to evaluate the assessor's ability to discriminate between the two products (Amerine *et al.* 1965). Tests were performed in the sensory booths at the university under artificial lighting. Each assessor was presented with a sample of conventionally prepared chicken and sauce labelled 'control' followed by two coded samples, one prepared conventionally and one by the sous vide method. Assessors were given a form (Appendix D.1-b) and asked if they could detect any differences between either of the coded samples and the control and if so, which coded sample was least like the control. They were then asked to describe these differences and mark a 6 point scale according to the acceptability of the two coded samples. The scores were assigned as follows :- 1 = Totally unacceptable, 2 = Moderately unacceptable, 3 = Just unacceptable, 4 = Just acceptable, 5 = Moderately acceptable, 6 = Totally acceptable.

Three experimental conditions were used to compare the freshly-prepared conventionally cooked dish against the freshly cooked sous vide dish and then repeated on the sous vide dish stored for up to 12 days at 3 °C. These three conditions (I, II, III) are denoted as follows :-

I - Conventional versus fresh sous vide

II - Conventional versus 5 day sous vide

III - Conventional versus 12 day sous vide.

As it was possible that a colour change noted in the sauce after sous vide cooking was influencing the assessors, a further condition was tested where the lightened sauce was replaced by freshly-prepared sauce immediately after reheating :-

IV - Conventional versus 12 day sous vide with fresh sauce.

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13 Multivac Ltd, Rivermead Drive, Swindon, Wilts, U.K.

14 Rational U.K. Ltd, Portenway Business Park, Luton, Beds, U.K.

15 Kane May, London, U.K.

2.1.3 Results from Experiment 1

The data from the Duo-Trio tests (Table 4) were tested for significance using tables in Amerine *et al.* (1965). The acceptability scores were entered from Microsoft Excel spreadsheets (Version 4.0) (Microsoft 1993) into Statview (Version 4.01) (Abacus Concepts 1992) for analysis of variance.

Condition	No. of assessors	No. identifying sous vide as different	No. identifying control as different	No. identifying no difference	Significance
I	17	16	1	0	$p<0.001$
II	35	33	1	1	$p<0.001$
III	14	13	1	0	$p<0.001$
IV	32	21	7	4	$p>0.05$ - not significant

Table 4. Numbers discriminating between conventionally cooked and sous vide processed chicken in red wine sauce.

The results of the Duo-Trio tests illustrated that assessors could discriminate between the conventionally prepared dish (the control) and the sous vide version immediately after cooking and then after 5 and 12 days of chilled storage followed by reheating ($p<0.001$). However, replacing the lightened sauce by freshly-prepared sauce made the level of discrimination much lower ($p>0.05$).

The reasons given by assessors for discriminating between the samples are summarised in Table 5. The most common reasons given as a proportion of the number in that group, for selecting the sous vide version as different, were the paler appearance of the chicken, its blander flavour and a weaker, watery sauce.

Table 6 shows the mean acceptability scores for the conventionally cooked Chicken in Red Wine sauce compared with the sous vide prepared dishes immediately after cooking (I) and at 5 days (II) and 12 days (III) of refrigerated storage. There was no significant difference between mean scores for each condition for the conventionally cooked control ($p>0.05$) but in each case the mean score for the sous vide dish was significantly lower ($p<0.01$). The freshly made sous vide dish (Condition I) was also significantly less acceptable than the 5 day (Condition II) and 12 day with fresh sauce (Condition IV) ($p<0.01$). The mean difference between scores was significantly greater for Condition I compared to the other conditions ($p<0.05$).

	Conditions →	I SV	I C	II SV	II C	III SV	III C	IV SV	IV C
	Total number →	16	1	33	1	13	1	21	7
	Description ↓								
Chicken	Paler	4	0	14	0	2	0	1	0
	Unappealing	0	0	3	0	0	0	0	0
	Tougher	3	0	4	0	5	0	2	2
	More tender	0	0	2	0	1	0	3	0
	Drier	2	0	2	1	2	0	0	0
	Juicier	2	0	0	0	0	0	2	0
	Blander	4	0	11	0	2	1	2	0
	Stronger	1	0	6	0	0	0	7	1
	More winey	0	0	0	0	0	0	2	0
	Less winey	1	0	2	0	1	0	0	0
Sauce	Paler	1	0	5	0	2	0	2	0
	Stronger	0	0	0	0	0	0	2	0
	Weaker	0	0	4	0	1	0	0	0
	Watery	3	0	4	0	1	0	1	0

Table 5. Frequency of words used by assessors to describe the differences between conventionally cooked (C) and sous vide processed (SV) chicken in red wine sauce.

Condition	Number of subjects	Mean score for conventional (control) (s. d.)	Mean score for sous vide (s. d.)	Mean difference between scores (s. d.)
I	17	5.31_{a} (0.67)	2.5_{c} (1.32)	2.81_{a} (1.21)
II	35	5.43_{a} (0.75)	3.69_{b} (1.16)	1.75_{b} (1.26)
III	14	4.36_{a} (1.50)	3.00_{bc} (1.24)	1.36_{b} (2.02)
IV	32	5.17_{a} (1.00)	3.95_{b} (1.55)	1.22_{b} (1.79)

Means in the two columns above with subscripts containing different letters are significantly different ($p<0.01$)

Means in the column above with subscripts containing different letters are significantly different ($p<0.05$)

Table 6. Results of acceptability assessment between conventionally cooked and sous vide processed chicken in red wine sauce.

2.1.4 Discussion of results from Experiment 1

This experimental work on a chicken dish has shown that the sous vide process can cause differences in appearance which easily distinguish it from the conventionally prepared version. This was due to a lightening effect on the red wine sauce and the chicken itself. A similar effect on sauce in sous vide processed foods has been observed in work elsewhere (Grant 1993). In research on discrimination, Church (1990) used a triangle test and found that conventionally and sous vide prepared Chicken Ballotine could be distinguished on attributes of 'filling moistness, chicken juiciness, aroma depth and initial flavour', although the direction of preference for these differences was not stated. Goto *et al.* (1995) used paired comparison tests for sous vide and conventionally prepared Chicken boiled in cream,

finding no differences for 'appearance, colour, flavour, taste, softness and preference'. Light *et al.* (1988) found no difference with Chicken à la King comparing freshly processed and stored sous vide dishes using a form of paired comparison test. In further work on Chicken Ballotine, again comparing freshly processed and stored sous vide dishes, consumers using a triangle test found differences where a trained panel using descriptive analysis could not (Schafheitle and Light 1989a, b).

In the present work, the initial sensory stimulus of paleness of sauce and chicken could have acted as a cue to change expectations and influence the score for acceptability. This corresponds with work showing that colour stimuli act as cues to odour recognition (Blackwell 1995). The effect was partially removed by substituting fresh sauce for the lightened sauce immediately after reheating the pack. This emphasises the strong effect of the appearance of a meal component on the ability of a consumer to discriminate.

Despite the fact that most commercial sous vide products incorporate sauce (Creed 1992), research on the effect of the properties of sauce on the acceptability of sous vide products is relatively scarce; Vogelaers (1996) discussed industrial-scale production and ingredients for sauce for sous vide products; others have examined the effect of starches on the stability of sauces in chilled prepared foods in general (Harkema 1995; Bouvier 1995).

Many commercial producers have offered 'sous vide' processed sauces but this description is probably misleading. Vacuum packaging solid and liquid meal components for sous vide processing implies that there can be no movement of solid components and some movement due to convection for liquid components during the cooking process. In contrast, conventional sauce preparation requires movement of liquid by convection and reduction by evaporation as well as physical mixing. This cannot happen in the sous vide process so the process offers no advantage for sauce preparation (Vogelaers 1996). Sauces must therefore be prepared beforehand and portioned into the sous vide pouch with the solid ingredients. Therefore the sauce should be able to withstand the sous vide heating process and the final reheating for serving without any degradation of its desired properties.

The question of modifying recipes to produce an acceptable product has not been covered in any scientific literature: work on sous vide dishes seem to have only covered variations within the process itself rather than attempting to determine objectively whether the product is superior to its conventionally prepared version. This first experiment emphasises that the sous vide process is not simply vacuum packing and then cooking at a relatively low temperature but also requires recipe modification, in this case, the sauce. This therefore begs the question of how these two factors - processing conditions and recipe modification - contribute towards any

enhanced sensory qualities. Until this has been proved, further investigations may be based on false assumptions. If there is no initial superiority in sensory qualities immediately after processing over conventionally cooked foods, it is unlikely that any enhancement will develop during chilled or frozen storage or reheating.

To summarise, experiments in a sensory laboratory under controlled conditions using 14 to 35 untrained assessors revealed significant discrimination ($p<0.001$) between:-

- the fresh sous vide chicken dish and the control (freshly prepared).
- the 5 day stored sous vide chicken dish and the control (freshly prepared).
- the 12 day stored sous vide chicken dish and the control (freshly prepared).

Comments from assessors revealed the reasons were that the sous vide version had paler, blander chicken with a weaker, watery flavoured sauce. In terms of acceptability, the sous vide version was regarded as significantly less acceptable ($p<0.01$). Therefore under laboratory conditions the sous vide processed chicken dish was significantly different and significantly inferior in acceptability compared to the conventionally prepared chicken dish.

2.1.5 Conclusions from Experiment 1

This stage of the empirical research has met the first objective and has determined that consumers can discriminate between a conventionally and sous vide processed dish. This result shows agreement with other research on the sensory aspects of sous vide foods (Appendix B). Therefore it does not support the opinions of chefs that sous vide products have superior sensory qualities. This may be due either to the effect of the processing conditions being too severe in order to ensure microbiological safety, or possibly that the sensory evaluation techniques employed by scientists have not been measuring what the chef perceives - the pleasure of eating. As discussed in section 1.4.6, the sensory evaluation techniques employed may not have been measuring what the chef has perceived. If there is a difference when experiments are conducted in the controlled environment of a sensory laboratory, it leads one to consider whether a difference could be perceived in a more ecologically valid environment, a restaurant with customers unaware of any experimentation.

2.2 Experiment 2 - To measure the ideal qualities of conventionally and sous vide cooked foods eaten in an ecologically valid environment.

2.2.1 Introduction

The objective of the second experiment of the empirical research was to measure the ideal qualities of conventionally and sous vide cooked foods eaten by assessors in an ecologically valid environment using customers in the university training restaurant.

2.2.2 Materials and methods

For this experiment, the dishes used, Lamb Navarin and Chicken Dijonnaise, were two of the highest selling items from a range of sous vide processed products manufactured by a U.K. sous vide manufacturer (Larderfresh 1997). The manufacturer supplied the recipes as shown in Appendix D.2-a. This enabled the dishes to be prepared conventionally in the kitchen of the university training restaurant to the same specification as the commercial sous vide recipe. The procedures used for the conventionally prepared dishes are also shown in Appendix D.2-a. Colour photographs of the commercially produced product in the manufacturer's sales literature were used as a guide for presentation of the conventionally prepared dishes and reheated sous vide dishes.

The sous vide versions were collected at the beginning of the week of service from the manufacturer and transported in an insulated box packed with ice. At the end of the 3 hour journey, the temperature between the sous vide packs was 3° to 4°C measured using a Kane May electronic thermometer accurate to ± 0.5 °C.

A questionnaire was piloted and modified as necessary (Appendix D.2-b). It incorporated questions on the demographic details of the respondent, their frequencies of eating out, eating at the university restaurant and eating that particular food. Further questions assessed the level of anticipation of enjoying the meal occasion, the hedonic response, the attributes of dish components on a relative-to-ideal scale and the hedonic response again.

The assessors were customers of the university training restaurant. This restaurant is open to members of the public and university staff and students. Its atmosphere is that of a formal restaurant with staff in formal dress, silver service, unobtrusive music, concealed lighting and curtained walls. The menu included a choice of six main courses, two of which were Lamb Navarin and Chicken Dijonnaise. It should be emphasised that this was a free choice test and therefore the frequency of take up of these dishes could not be predicted. Those customers who had eaten Lamb Navarin or Chicken Dijonnaise were approached after eating their

dessert and before their coffee and asked if they would participate in a survey aimed at improving the quality of meals served in the restaurant. The opportunity to use any point along the scales was emphasised and the questionnaires were collected when completed.

In Week 1 of the experiment, conventionally cooked versions of the Lamb Navarin and Chicken Dijonnaise were served; in Week 2 the sous vide versions and in Week 3, the conventionally cooked versions again.

The scores from the questionnaire were measured in millimetres from the scales (Appendix D.2-b); 0 to 112 mm for the anticipation (Likert) scale, 0 to 139 mm for the hedonic scales and -45 to +45 mm for the relative-to-ideal scales. These raw data were transformed into desirability values (d), discussed earlier in section 1.5.8, using the criteria in Table 7, also shown graphically in Figure 14. These transformations are based on an assumption of linear variation of desirability value (d) with attribute scores (y). For example, an assessor's scores (measured in mm) on the anticipation, hedonic and one of the relative-to-ideal scales of 28 (Agree), 105 (between 'Like slightly' and 'Like moderately') and -12 (left of the ideal point) respectively would be transformed by dividing the distance above the point where d = 0, by the distance between the points where d = 1 and 0:-

Anticipation:- $$d = \frac{(28-56)}{(0-56)} = \frac{-28}{-56} = 0.5$$

Hedonic:- $$d = \frac{(104-69.5)}{(139-69.5)} = \frac{34.5}{69.5} = 0.496$$

Relative-to-ideal $$d = \frac{(-12--22.5)}{(0--22.5)} = \frac{10.5}{22.5} = 0.467$$

These examples are also shown by the dotted lines in Figure 18. The transformations from measured raw data to desirability values were performed by formulas written into the Excel spreadsheets.

Scale	Desirability = 0	Desirability = 1
Anticipation	56 (Neither agree/disagree) and above	0 (Strongly agree)
Hedonic	69.5 (neither like nor dislike) and below	139 (Like extremely)
Relative-to-ideal	-22.5 and below / +22.5 and above (Halfway between 'Ideal' and 'Far too ...' anchor points	0 (Ideal)

Table 7. Criteria for transforming raw data (y) (measured in mm) from scales to desirability values (d).

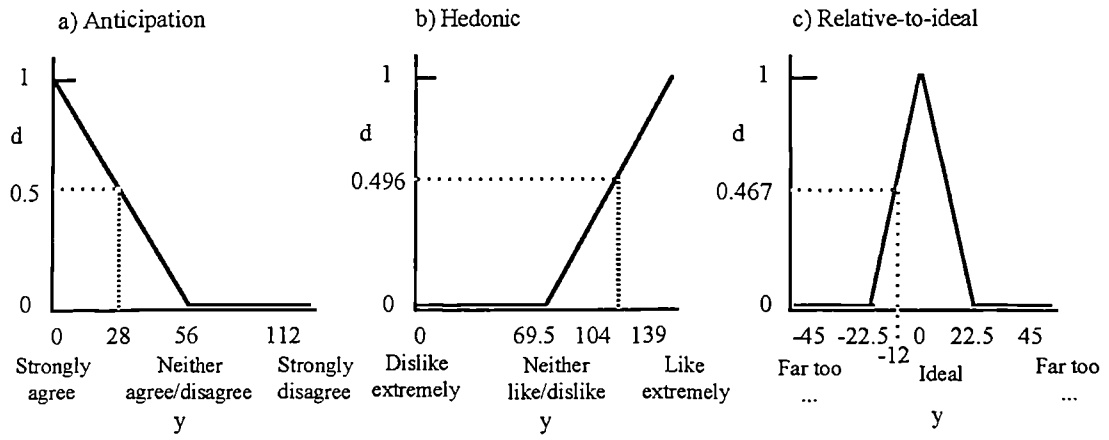


Figure 18. Linear transformations from raw data (y) to desirability values (d) for questionnaire scales (Appendix D.2-b).

For individual consumers a mean Desirability Score (D), was calculated which combined the individual desirability values from each attribute by calculating the geometric mean:-

$$D = (d_1 d_2 d_3 \ldots d_n)^{1/n}$$

Where - d_1, d_2 etc. are individual desirability values from different attributes and n = number of attributes.

Desirability values (d) are the transformed attribute scores and Desirability Score (D) is the geometric mean of an individual assessor's desirability values. Therefore if any single attribute has a desirability value of zero, then that assessor's Desirability Score will also become zero. For example, if an assessor's desirability values derived from six attributes were 0.34, 0.65, 0.9, 0.5, 0.7 and 0.87, the Desirability Score for that assessor would be:-

$$D = (0.34 \times 0.65 \times 0.9 \times 0.5 \times 0.7 \times 0.87)^{1/6} = (0.06056505)^{1/6} = 0.627$$

2.2.3 Results from Experiment 2

Over the three weeks of the experiment, 77 questionnaires were completed with only one refusal (Table 8). Data were entered from Excel spreadsheets into StatView (Macintosh) for analysis of variance (ANOVA) and Chi squared tests leading to contingency tables.

Dish	**Week 1** (conventional)	**Week 2** (sous vide)	**Week 3** (conventional)	**Total**
Lamb Navarin	15	19	7	41
Chicken Dijonnaise	9	16	11	36
Totals	24	35	18	77

Table 8. Number of assessors in each week for each dish.

The distribution of age groups by gender and treatment (conventional or sous vide) is shown in Table 9.

		Age Group						
Gender	**Treatment**	**18 - 25**	**26 - 35**	**36 - 45**	**46 - 55**	**56 - 65**	**over 65**	**Totals**
Male	conventional	0	4	9	9	1	4	27
	sous vide	1	1	3	5	2	2	14 (+ 1*)
Female	conventional	1	1	2	4	2	5	15
	sous vide	0	1	3	4	3	9	20
	Totals	2	7	17	22	8	20	76

Table 9. Distribution of age groups by gender and food treatment (with 1 missing value).

The age group distribution was typical of the usual restaurant clientele with peaks at the 36 to 55 and over 65 age groups, university staff and the retired respectively.

Analysis of variance (ANOVA) was performed on the raw data to determine any significant differences between weeks 1, 2 and 3 and in addition between combined data from weeks 1 and 3 (conventional) and week 2 (sous vide). For any significant F values, i.e. those with $p \leq 0.05$, the Scheffé's S *post hoc* test was applied to determine the location of the differences (Abacus Concepts 1992). An example is shown in Table 10 for the texture attributes of Chicken Dijonnaise. The first ANOVA analyses the weeks separately and the second compares Weeks 1 and 3 combined (conventional) with Week 2 (sous vide).

(a)

ANOVA Table for TeCh

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Week	2	775.959	387.979	2.575	.0914
Residual	33	4972.347	150.677		

Means Table for TeCh
Effect: Week

	Count	Mean	Std. Dev.	Std. Err.
1	9	7.000	12.207	4.069
2	16	-3.688	12.616	3.154
3	11	4.091	11.802	3.558

Scheffe for TeCh
Effect: Week
Significance Level: 5 %

	Mean Diff.	Crit. Diff	P-Value
1, 2	10.688	13.110	.1287
1, 3	2.909	14.142	.8707
2, 3	-7.778	12.323	.2838

(b)

ANOVA Table for TeCh

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Treat	1	734.068	734.068	4.977	.0324
Residual	34	5014.237	147.478		

Means Table for TeCh
Effect: Treatment

	Count	Mean	Std. Dev.	Std. Err.
s.v.	16	-3.688	12.616	3.154
conv.	20	5.400	11.758	2.629

Scheffe for TeCh
Effect: Treatment
Significance Level: 5 %

	Mean Diff.	Crit. Diff	P-Value	
s.v., conv.	-9.088	8.278	.0324	S

Table 10. Examples of ANOVA's and *post hoc* tests, comparing (a) Weeks 1, 2, and 3. (b) Weeks 1 and 3 combined (conventional) with Week 2 (sous vide)

The summarised results of analysis for all attributes are shown in Table 11 for Chicken Dijonnaise and Table 12 for Lamb Navarin.

ANOVA by Week	Week							
Attribute	1 Mean	(n=9) s.d.	2 Mean	(n=16) s.d.	3 Mean	(n=11) s.d.	F-value	p
Anticipation *	41.22a	12.13	24.56b	13.07	25.00ab	19.72	3.969	0.029
		p=0.043						
Liking before ‡	103.00	25.75	117.38	18.92	117.91	25.82	1.369	0.268
Amount of chicken	6.67	13.07	5.88	22.50	1.82	4.24	0.266	0.768
Amount of sauce	-8.11	28.80	9.44	22.21	-4.91	14.79	2.305	0.116
Amount of vegetables	-3.44	14.71	0.81	27.13	-0.55	6.73	0.131	0.878
Size of vegetables	-3.78	13.26	3.00	19.82	-2.46	7.70	0.699	0.504
Colour of chicken	-7.22	14.87	-4.19	16.28	-9.73	18.42	0.369	0.695
Colour of vegetables	0.44	6.43	2.19	12.00	0.64	2.58	0.155	0.857
Colour of sauce	-2.33	4.27	-0.94	7.97	-4.00	12.51	0.380	0.687
Texture of chicken	7.00	12.21	-3.69	12.62	4.09	11.80	2.575	0.091
Texture of sauce	0.22	20.17	-4.44	15.26	-7.82	16.82	0.552	0.581
Flavour of chicken	-3.78	8.26	-8.75	19.54	-9.55	13.82	0.390	0.680
Flavour of sauce	8.67a	14.57	-7.25b	14.83	-1.27ab	3.26	4.720	0.016
		p=0.16						
Liking after ‡	105.33	22.04	106.88	26.84	117.64	23.06	0.818	0.450

ANOVA by Treatment	Week					
Attribute	2 Mean	(n=16) s.d.	1 & 3 Mean	(n=20) s.d.	F	p
Anticipation *	24.56	13.07	32.30	18.31	2.026	0.164
Liking before ‡	117.38	18.92	111.20	26.23	0.625	0.435
Amount of chicken	5.88	22.50	4.00	9.35	0.115	0.737
Amount of sauce	9.44a	22.21	-6.35b	21.61	4.628	0.039
Amount of vegetables	0.81	27.13	-1.85	10.82	0.161	0.690
Size of vegetables	3.00	19.82	-3.05	10.28	1.401	0.245
Colour of chicken	-4.19	16.28	-8.60	16.53	0.642	0.429
Colour of vegetables	2.19	12.00	0.55	4.57	0.317	0.577
Colour of sauce	-0.94	7.97	-3.25	9.53	0.604	0.443
Texture of chicken	-3.69a	12.62	5.40b	11.76	4.977	0.032
Texture of sauce	-4.44	15.26	-4.20	18.36	0.003	0.967
Flavour of chicken	-8.75	19.54	-6.95	11.74	0.117	0.734
Flavour of sauce	-7.25a	14.83	3.20b	10.99	5.902	0.021
Liking after ‡	106.88	26.84	112.10	22.89	0.398	0.533

Table 11. Chicken Dijonnaise - mean values and standard deviations of attributes with ANOVA F statistic and significance level analysed by Week and by Treatment. Means in same row with different subscripts are significantly different at level shown.
* Measured from 0 = Agree strongly to 112 = Disagree strongly. ‡ Measured from 0 = Dislike extremely to 139 = Like extremely. All other attributes measured from -45 = Far too ..... to +45 = Far too ..... as shown in Appendix D 2-b.

ANOVA by Week	Week							
	1	(n=15)	2	(n=19)	3	(n=7)	F-	
Attribute	Mean	s.d.	Mean	s.d.	Mean	s.d.	value	p
Anticipation *	28.80	15.70	22.21	17.94	19.14	13.15	1.056	0.358
Liking before ‡	113.07	25.41	106.42	27.46	119.71	16.62	0.778	0.467
Amount of lamb	-6.33	16.55	-0.63	13.76	-6.86	17.03	0.745	0.481
Amount of mushroom	-12.27	25.24	-4.37	19.83	3.29	7.46	1.446	0.248
Amount of carrots	-3.60	22.11	3.05	15.70	2.57	4.96	0.675	0.515
Size of lamb	-10.67	13.64	-4.63	18.56	0.86	2.27	1.486	0.239
Size of mushroom	-2.20	6.75	2.47	14.18	-2.00	4.47	0.942	0.399
Size of carrots	-1.87	10.13	8.26	19.22	5.14	9.92	1.907	0.162
Colour of lamb	4.40	15.95	15.21	22.31	1.14	3.02	2.238	0.121
Colour of mushroom	1.60	2.67	5.95	14.42	0.86	4.49	1.039	0.364
Colour of carrots	-3.60	8.56	1.90	12.49	1.86	2.61	1.404	0.258
Colour of sauce	7.93	16.18	12.05	16.97	1.57	5.29	1.218	0.307
Texture of lamb	-2.93	8.32	1.58	12.13	0.43	2.15	0.911	0.411
Texture of sauce	1.27	11.54	0.95	14.65	14.57	17.88	2.625	0.086
Flavour of lamb	-3.47	10.64	-4.74	17.45	-9.71	16.86	0.415	0.663
Flavour of sauce	7.80a	18.39	2.84ab	10.48	-12.43b	20.39	4.076	0.025
			p=0.026					
Liking after ‡	113.53	23.91	107.84	28.14	119.71	17.43	0.615	0.546

ANOVA by Treatment	Week					
	2	(n=19)	1 & 3	(n=22)		
Attribute	Mean	s.d.	Mean	s.d.	F	p
Anticipation *	22.21	17.94	25.73	15.33	0.459	0.502
Liking before ‡	106.42	27.46	115.18	22.79	1.247	0.271
Amount of lamb	-0.63	13.76	-6.50	16.29	1.524	0.224
Amount of mushroom	-4.37	19.83	-7.32	22.26	0.198	0.659
Amount of carrots	3.05	15.70	-1.64	18.48	0.753	0.391
Size of lamb	-4.63	18.56	-7.00	12.48	0.236	0.630
Size of mushroom	2.47	14.18	-2.14	6.01	1.931	0.173
Size of carrots	8.26	19.22	0.36	10.38	2.785	0.103
Colour of lamb	15.21a	22.31	3.36b	13.22	4.419	0.042
Colour of mushroom	5.95	14.42	1.36	3.26	2.105	0.155
Colour of carrots	1.90	12.49	-1.86	7.59	1.399	0.244
Colour of sauce	12.05	16.97	5.91	13.85	1.630	0.209
Texture of lamb	1.58	12.13	-1.86	7.07	1.275	0.266
Texture of sauce	0.95	14.65	5.50	14.84	0.971	0.331
Flavour of lamb	-4.74	17.45	-5.46	12.87	0.023	0.881
Flavour of sauce	2.84	10.48	1.36	20.91	0.078	0.782
Liking after ‡	107.84	28.14	115.50	21.83	0.961	0.333

Table 12. Lamb Navarin - mean values and standard deviations of attributes with ANOVA F statistic and significance level analysed by Week and by Treatment. Means in same row with different subscripts are significantly different at level shown.
* Measured from 0 = Agree strongly to 112 = Disagree strongly. ‡ Measured from 0 = Dislike extremely to 139 = Like extremely. All other attributes measured from -45 = Far too ..... to +45 = Far too ..... as shown in Appendix D 2-b.

It is normally the convention that p = 0.05 is the highest probability for two means to be considered significantly different. On this basis, the level of anticipation of enjoyment was significantly greater in Week 2 than in Week 1 ($p<0.05$). The flavour of the sauces with the Chicken Dijonnaise prepared conventionally (Weeks 1

& 3) was significantly stronger than the sous vide version ($p<0.05$). The amount of sauce in the conventionally prepared dish was significantly less than the sous vide dish ($p<0.05$). The texture of sous vide processed chicken was significantly more tender than the conventional versions ($p<0.05$).

Unlike consumers of Chicken Dijonnaise, no significant differences in anticipation of enjoyment between the weeks of experiment were shown by consumers of Lamb Navarin ($p<0.05$). The flavour of the sauce in the Lamb Navarin prepared conventionally in Week 3 was significantly weaker than in Week 1 ($p<0.05$) but neither were different from the flavour of the sous vide version ($p>0.05$). The only other significant difference was that the colour of sous vide lamb was considered significantly darker than the conventionally prepared version ($p<0.05$) (Table 12).

Although not significant at $p = 0.05$, the texture of the Lamb Navarin sauce ($p = 0.086$ for F statistic) was much thicker in Week 3 (conventional) than in Week 2 (sous vide).

The summarised results of the data transformed into desirability values, are given in Table 13 for Chicken Dijonnaise and Table 14 for Lamb Navarin. They highlight those attributes of the two dishes which came closest to ideal, i.e. a desirability value of 1.

In the case of Chicken Dijonnaise, those attributes closest to ideal ($d = 1$) were the colour of the vegetables and sauce ($d > 0.8$) and for Lamb Navarin the colour of the mushrooms and carrots and the size of the mushrooms ($d > 0.8$). For the Chicken Dijonnaise there were fewer significant differences between conventional and sous vide processing than for Lamb Navarin. The level of anticipation of enjoyment of those eating Chicken Dijonnaise in Week 1 was less desirable than in the other weeks ($p<0.05$) and the amount of vegetables with the sous vide dish was less desirable than with the conventional version ($p<0.05$). For the Lamb Navarin, the amount of mushrooms in Week 1 was considered less desirable than in the other weeks ($p<0.05$) and the desirability of the size of lamb pieces in Weeks 1 and 3 was significantly different ($p<0.05$). The colour of the sous vide lamb was less desirable than that with the conventional version ($p<0.05$), due to the darker colour. The mean Desirability Score in Week 1 was significantly less than in Week 3 ($p<0.05$).

Week	Anticip-ation	Liking before	Amount of chicken	Amount of sauce	Amount of vegetables	Size of vegetables
all	0.486	0.670	0.756	0.556	0.667	0.719
1	0.266_a	0.530	0.731	0.294	0.760	0.864
2	0.561_b	0.702	0.692	0.585	0.514	0.592
3	0.555_b	0.739	0.871	0.727	0.814	0.786
p	0.028	0.222	0.416	0.070	0.082	0.160
1&3	0.425	0.645	0.808	0.532	0.790_a	0.821
2	0.561	0.702	0.692	0.585	0.514_b	0.592
p	0.169	0.556	0.324	0.720	0.026	0.062

	Colour of chicken	Colour of vegetables	Colour of sauce	Texture of chicken	Texture of sauce	Flavour of chicken
all	0.694	0.827	0.831	0.729	0.711	0.672
1	0.751	0.783	0.847	0.669	0.635	0.785
2	0.714	0.785	0.810	0.733	0.742	0.636
3	0.620	0.923	0.848	0.772	0.729	0.632
p	0.678	0.276	0.906	0.797	0.763	0.600
1&3	0.679	0.860	0.848	0.726	0.687	0.701
2	0.714	0.785	0.810	0.733	0.742	0.636
p	0.765	0.352	0.654	0.946	0.650	0.616

	Flavour of sauce	Liking after	Mean of individual Desirability Scores (D)
all	0.728	0.608	0.234
1	0.548	0.549	0.129
2	0.703	0.563	0.212
3	0.911	0.723	0.352
p	0.051	0.365	0.391
1&3	0.748	0.645	0.252
2	0.703	0.563	0.212
p	0.699	0.448	0.756

Table 13. Mean desirability values for Chicken Dijonnaise, overall and for each week (1 & 3 - Conventional, 2 - Sous vide) for attributes from Appendix D.2 and mean of individual Desirability Scores (D). Means in columns bearing subscripts with different letters are significantly different ($p < 0.05$).

Week	Antici-pation	Liking before	Amount of lamb	Amount of mushroom	Amount of carrots	Size of lamb	Size of mushroom
all	0.571	0.621	0.650	0.543	0.664	0.702	0.814
1	0.486	0.648	0.479	0.271_a	0.516	0.560_a	0.831
2	0.607	0.561	0.730	0.642_b	0.699	0.718_{ab}	0.764
3	0.658	0.723	0.800	0.854_b	0.886	0.962_b	0.911
p	0.338	0.455	0.089	0.004	0.116	0.046	0.506
1 & 3	0.541	0.672	0.581	0.457	0.633	0.688	0.857
2	0.607	0.561	0.730	0.642	0.699	0.718	0.764
p	0.471	0.251	0.224	0.182	0.607	0.793	0.313

	Size of carrots	Colour of lamb	Colour of mushroom	Colour of carrots	Colour of sauce	Texture of lamb	Texture of sauce
all	0.708	0.607	0.846	0.807	0.638	0.790	0.668
1	0.750	0.656_{ab}	0.923	0.775	0.618	0.727	0.684
2	0.643	0.442_a	0.771	0.792	0.571	0.782	0.694
3	0.794	0.949_b	0.886	0.917	0.867	0.943	0.562
p	0.596	0.018	0.163	0.573	0.218	0.305	0.729
1 & 3	0.764	0.749_a	0.911	0.820	0.697	0.796	0.645
2	0.643	0.442_b	0.771	0.792	0.571	0.782	0.694
p	0.321	0.019	0.059	0.768	0.302	0.889	0.691

	Flavour of lamb	Flavour of sauce	Liking after	Mean of individual Desirability Scores (D)
all	0.671	0.623	0.633	0.238
1	0.681	0.493	0.657	0.079_a
2	0.657	0.724	0.582	0.225_{ab}
3	0.686	0.625	0.723	0.613_b
p	0.926	0.239	0.538	0.007
1 & 3	0.683	0.535	0.678	0.249
2	0.657	0.724	0.582	0.225
p	0.825	0.126	0.311	0.847

Table 14. Mean desirability values for Lamb Navarin, overall and for each week (1 & 3 - Conventional, 2 - Sous vide) for attributes from Appendix D.2 and mean of individual Desirability Scores (D). Means in columns bearing subscripts with different letters are significantly different ($p < 0.05$).

Again, although not significant at $p = 0.05$, the flavour and amount of the Chicken Dijonnaise sauce ($p = 0.052$ and 0.070 respectively for F statistics) were more desirable in Week 3 (conventional) than in Week 1 (conventional). The size of

vegetables with the Chicken Dijonnaise was also more desirable in Weeks 1 and 3 combined (conventional) compared to Week 2 (sous vide) ($p = 0.062$ for F statistic). For the Lamb Navarin, the colour of the sous vide mushrooms was considered less desirable than the conventional version ($p = 0.059$).

Using the paired t-test, the mean hedonic scores (Liking before and Liking after), both as raw data and desirability values were compared overall, by food type and by processing treatment (Table 15).

Comparison	Data	Difference between means	No pairs	p
Overall	Raw	1.455	77	0.362
	d	0.021	77	0.342
All sous vide	Raw	3.971	35	0.216
	d	0.051	35	0.257
All conventional	Raw	-0.643	42	0.595
	d	-0.003	42	0.823
All lamb	Raw	-0.829	41	0.699
	d	-0.013	41	0.679
All chicken	Raw	4.056	36	0.090
	d	0.060	36	0.070
SV lamb	Raw	-1.421	19	0.747
	d	-0.020	19	0.744
SV chicken	Raw	10.375	16	0.026
	d	0.137	16	0.036
Conventional lamb	Raw	-0.318	22	0.831
	d	-0.005	22	0.783
Conventional chicken	Raw	-1.000	20	0.618
	d	-0.001	20	0.958

Table 15. Paired t-test between Liking after and Liking before for all data, by food type and by processing treatment (d indicates data transformed into desirability values).

Only one significant difference was found ($p<0.05$) for sous vide processed Chicken Dijonnaise where the hedonic score fell after the dish's attributes had been considered.

Regression equations were also determined for the correlation between the assessors' hedonic score after examining the food's attributes using the relative-to-ideal scales (Liking after), to the hedonic score given before (Liking before) (Table 16).

All regression coefficients were significantly different from 0 ($p<0.0001$). The coefficients for sous vide dishes were lower than for the conventionally cooked

dishes for both the raw data from the hedonic scales and for the data transformed into desirability values. Regression plots for conventional and sous vide dishes (Figures 19 and 20) show the wider variation with the sous vide dishes.

Data/Treatment	Regression equation	r	r^2	No. pairs
Raw data				
Conventional	y = 15.812 + 0.866 x	0.948	0.898	42
Sous vide	y = 14.626 + 0.833 x	0.742	0.550	35
Desirability data				
Conventional	y = 0.091 + 0.867 x	0.926	0.857	42
Sous vide	y = 0.096 + 0.764 x	0.674	0.455	35

Table 16. Correlation between Liking after (y) and Liking before (x) for convention and sous vide treatments of Lamb Navarin and Chicken Dijonnaise dishes.

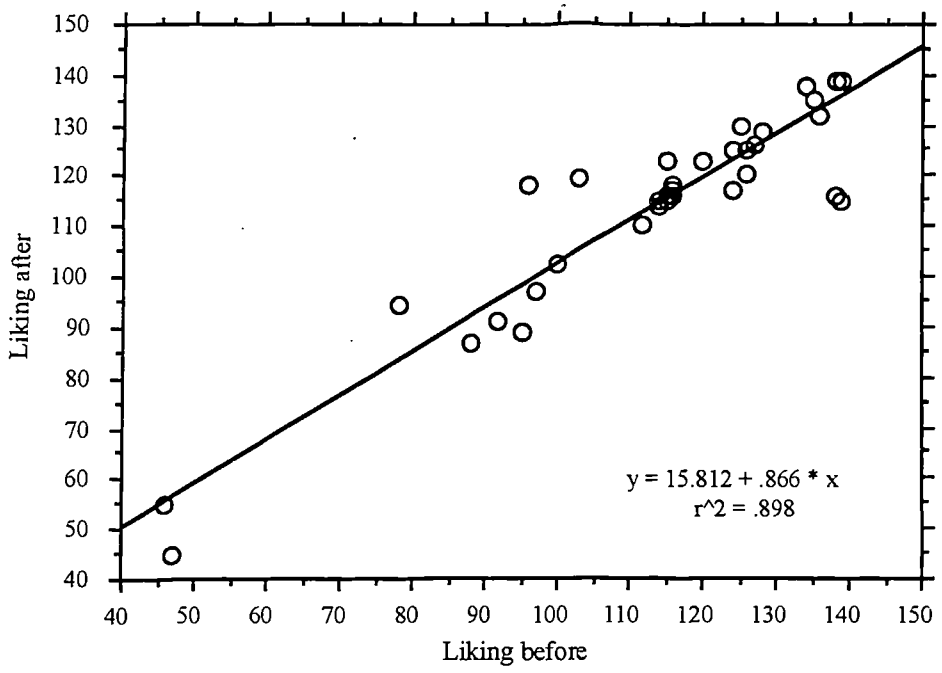


Figure 19. Plot of regression of Liking after (y) on Liking before (x) for conventional treatment of Lamb Navarin and Chicken Dijonnaise dishes. (0 = Dislike extremely, 139 = Like extremely).

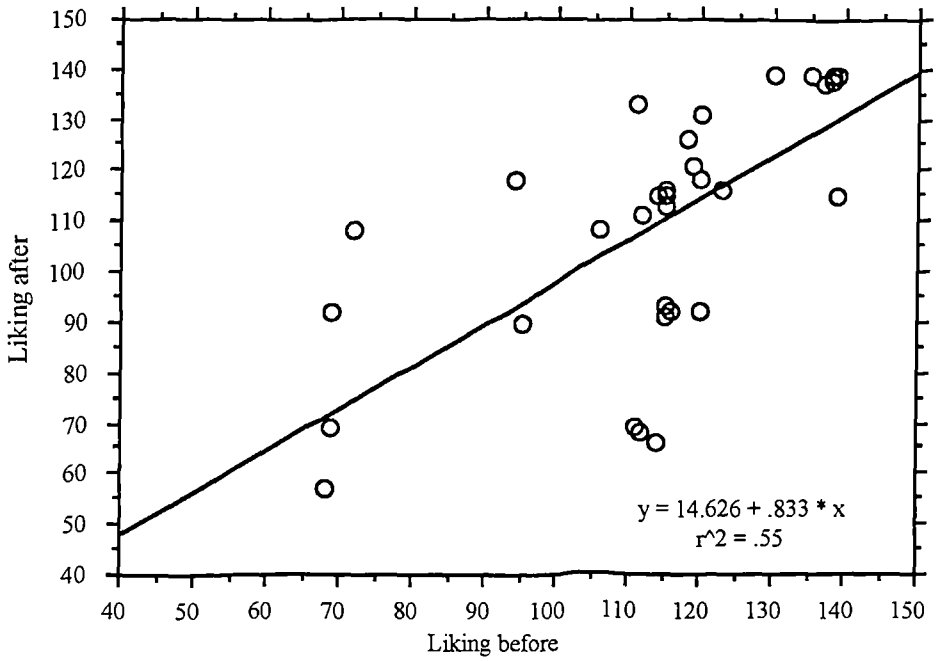


Figure 20. Plot of regression of Liking after (y) on Liking before (x) for sous vide treatment of Lamb Navarin and Chicken Dijonnaise dishes. (0 = Dislike extremely, 139 = Like extremely).

The data (raw and desirability values) were also subdivided according to demographic data. Analysis of variance with Scheffé's *post hoc* test revealed some significant differences ($p<0.05$) dependent on age group and gender. As some cell sizes in the seven age groups on the questionnaire (Appendix D.2-b) were small, the age groups were divided into two sets, those aged 45 and below (young) and those aged 46 and above (old) (Table 17).

The majority of differences appear to arise from anticipation of eating at the university restaurant and the hedonic scores (Liking before or after) with texture showing up as the only significant attribute for both dishes. Women liked the Chicken Dijonnaise more than the men ($p<0.05$) but found the texture of Lamb Navarin significantly tougher than men ($p<0.05$). The older customers liked the Chicken Dijonnaise more than the younger group ($p<0.05$) and found the texture more tender ($p<0.05$). The older customers eating Lamb Navarin had higher anticipation than the younger group ($p<0.05$) and liked the dish more ($p<0.05$). Combining the data from the two dishes showed again that the older customers had higher anticipation than the younger group ($p<0.05$).

Comparison	Attribute	Mean (male)	n	Mean (female)	n	p
Chicken	Liking before ¶	101.00	13	121.261	23	0.009
	Liking before (d)	0.516	13	0.757	23	0.012
Lamb	Texture ‡	-2.464	28	4.462	13	0.037

Comparison	Attribute	Mean (young)	n	Mean (old)	n	p
Chicken	Liking before ¶	101.33	12	120.25	24	0.015
	Liking before (d)	0.524	12	0.743	24	0.023
	Texture ‡	7.667	12	-1.792	24	0.037
Lamb	Anticipation *	31.64	14	19.89	26	0.036
	Anticipation (d)	0.440	14	0.645	26	0.039
	Liking after ¶	100.429	14	118.038	26	0.032
Lamb &	Anticipation *	31.962	26	23.360	50	0.033
Chicken	Anticipation (d)	0.433	26	0.583	50	0.035

Table 17. Chicken Dijonnaise and Lamb Navarin- attributes with significant differences defined by gender and age group. (d) signifies data transformed into desirability values. ¶ Measured from 0 = Dislike extremely to 139 = Like extremely, ‡ Measured from -45 = Far too tender to +45 = Far too tough, * Measured from 0 = Agree strongly to 112 = Disagree strongly.

Demographic data was also collected on frequency of eating out, frequency of eating at the university restaurant and frequency of eating lamb or chicken. Analysis of variance with Scheffé's *post hoc* test revealed some significant differences ($p<0.05$) dependent on these frequencies. As some cell sizes in the seven groups on the questionnaire (Appendix D.2-b) were small, the frequency groups were divided into two sets, those who ate once a month or more frequently (high) and those who ate less frequently (low) (Table 18).

Comparison	Attribute	Mean (high)	n	Mean (low)	n	p
Chicken	Colour ¶	-16.077	13	-1.304	23	0.007
	Flavour *	-16.154	13	-3.000	23	0.012
	Desirability Score (D)	0.073	13	0.325	23	0.046
Lamb	Texture of sauce ‡	-4.167	12	6.517	29	0.033
	Desirability Score (D)	0.430	12	0.159	29	0.038

Table 18. Chicken Dijonnaise and Lamb Navarin- attributes with significant differences defined by frequency of eating at the university restaurant. ¶ Measured from -45 = Far too pale to +45 = Far too dark, * Measured from -45 = Far too weak to +45 = Far too strong, ‡ Measured from -45 = Far too thin to +45 = Far too thick.

No significant differences ($p<0.05$) were found for the effect of frequency of eating out on any attributes of the Lamb Navarin and Chicken Dijonnaise. There were also no significant differences ($p<0.05$) for the effect of frequency of eating lamb but no meaningful results could be obtained from the analysis of variance for frequency of eating chicken because the response of 26 out of the 36 customers was 'once per week' so that no split could give groups of similar size. The results in Table 17 therefore apply only to the frequency of eating at the university restaurant. This shows those who ate once a month or more considered the Chicken Dijonnaise to be significantly paler and weaker in flavour than the less frequent customers ($p<0.05$). Those who ate once a month or more considered the Lamb Navarin sauce to be significantly thinner than the less frequent customers ($p<0.05$). The Desirability Scores were also significantly different ($p<0.05$) for the two groups with the less frequent customers having higher scores for the Chicken Dijonnaise but lower scores for the Lamb Navarin.

Analysis of variance is not the only statistical technique which can help to explain the structure of a large matrix of responses in a survey such as this. Factor analysis is a technique for 'analysing the patterns of complex, multi-dimensional relationships encountered by researchers and business people' (Hair *et al.* 1995). This technique was therefore used in the Statview program with the relevant attributes to determine which combination of attributes would explain the variation in response. The process is iterative, allowing attributes to be used or taken out. In this case, the attributes relevant to size and amount of meal components were omitted as they are certainly a constant factor in the portion-controlled manufactured sous vide meals and to a slightly less rigorous extent in conventionally prepared meals. Therefore the attributes of the food components, which were present in the sous vide pack, were entered for factor analysis. These were for the Lamb Navarin: colour, flavour and texture of both lamb and sauce and colour of carrots and mushrooms: for the Chicken Dijonnaise the attributes used were colour, flavour and texture of both chicken and sauce. The factors and their components with the corresponding factor loadings taken from the oblique solution primary pattern matrix, are shown in Table 19 for both Chicken Dijonnaise and Lamb Navarin. The criterion used for deciding whether factor loadings were significant ($p<0.05$) was a value of 0.75 for this number of samples (Hair *et al.* 1995). The complete oblique solution primary pattern matrices with summary tables and Eigen values, for the Chicken Dijonnaise and the Lamb Navarin are shown in Appendix E.1.

Lamb Navarin	Attribute	Factor loading	Chicken Dijonnaise	Attribute	Factor loading
Factor 1	Colour of lamb	0.850	**Factor 1**	Texture of chicken	0.913
Variance explained = 30.2%	Colour of sauce	0.850	Variance explained = 32.5%	Flavour of sauce	0.846
Factor 2	Flavour of lamb	0.829	**Factor 2**	Colour of chicken	0.824
Variance explained = 23.0%	Flavour of sauce	0.871	Variance explained = 24.2%	Flavour of chicken	0.884
Factor 3	Texture of lamb	0.781	**Factor 3**	Colour of sauce	0.865
Variance explained = 14.9%	Texture of sauce	0.862	Variance explained = 21.5%	Texture of sauce	0.797
Factor 4	Colour of carrots	0.886			
Variance explained = 11.3%	Colour of mushrooms	0.760			

Table 19. Factors from factor analysis of attributes of Lamb Navarin and Chicken Dijonnaise.

For the Lamb Navarin, Factor 1 is dominated by colour attributes, Factor 2 by flavour attributes, Factor 3 by texture attributes and Factor 4 by colour attributes specific to the vegetables. These four factors explain 79.4% of the variance. For the Chicken Dijonnaise, the factor characterisation is more difficult and applies more to the meal components rather than the dish's sensory properties, i.e. Factor 2 is dominated by chicken attributes, Factor 3 by sauce attributes and Factor 1, by the two attributes, chicken texture and sauce flavour, showing significant differences from the analysis of variance (Table 11). These three factors explain 78.2 % of the variance.

2.2.4 Discussion of results from Experiment 2

As this experiment was conducted in an ecologically valid environment, a restaurant, there was no possibility of controlling how many restaurant customers would choose the two particular dishes in order to obtain equal numbers of responses in each week of the experiment. The same also applied to other demographic factors such as gender and age group. Table 9 shows the relatively high number of people in the oldest age group (over 65 years) who are regular restaurant customers.

Although all the respondents who chose Chicken Dijonnaise, were looking forward to eating in the restaurant, there was a significant difference between those in Week 1 (41.22) and those in Week 2 (24.50) (Table 11). This was possibly due to the fact that more university staff happened to be using the restaurant in Week 1 which could cause an age effect discussed below. This effect was not significant when the data from Weeks 1 and 3 were combined. The weaker flavour of the sous

vide sauce with the Chicken Dijonnaise compared to the conventionally prepared version and the greater amount of sauce in the sous vide product compared to the conventionally prepared version both highlighted the difficulties in reproducing a commercial product in a restaurant kitchen.

One positive aspect was the more tender texture of the sous vide Lamb Navarin compared to the conventionally prepared version. In contrast, the colour of this product was considered too dark (Table 12). During the commercial manufacturing process, the cubes of lamb for this dish are browned by passing them through a continuous fryer for a short period before being weighed into the sous vide pouch. The result in this present research may indicate that the browning is too severe and causes a noticeable effect in the reheated dish.

This experiment in an ecologically valid environment has also shown that few significant differences between conventionally and sous vide processed versions of the same two dishes were apparent to the restaurant customers. This again emphasises that sous vide processed foods do not appear to provide the enhanced sensory properties claimed in Appendix A.1.

Consumer acceptability studies such as this, generally allow respondents only one opportunity to assess hedonic liking or acceptability. This experiment deliberately sought to determine if there had been any change in the respondents' hedonic score after assessing the particular food attributes in some detail. In general, consumers did not change their views except for sous vide processed Chicken Dijonnaise where the hedonic score fell significantly ($p<0.05$) (Table 15). The only attributes which changed significantly for this dish were chicken texture which was more tender and sauce flavour which was weaker than the conventionally prepared dish (Table 11). The mean desirability value of the amount of vegetables which accompanied the dish was also lower (Table 13). These changes may suggest that a consumer realising that the sauce was too weak and the chicken slightly too tender, could act as cues to lower the hedonic score for the whole dish.

Studying the correlation between the two hedonic scores also revealed that the correlation coefficient for sous vide foods was generally lower, again indicating more uncertainty and inconsistency in consumer responses (Table 16).

The significant differences shown for gender and age group (Table 17), show no consistent pattern apart from the younger age group not anticipating eating at the university restaurant with as much relish as the older group. This may be due to the younger group being mainly university staff having a working lunch while the older group are retired members of the public eating out as a special treat. The only significant differences relating to how frequently customers used the university restaurant, produced contradictory effects for Desirability Scores, low frequency users finding Chicken Dijonnaise more desirable but Lamb Navarin less desirable

than higher frequency customers (Table 18). These mean Desirability Scores would have been heavily influenced by the number of zero values caused when any attribute becomes zero.

Results from the factor analysis (Table 19) indicate how consumers perceive patterns of attributes. The Lamb Navarin factors start with colour as most important followed by flavour and texture, coinciding with the general belief that consumers assess acceptability of foods firstly through appearance, then flavour and finally texture which needs more time to assess. If the attributes making up Factor 1 are related to the hedonic responses (liking before/after) in Table 10, both the sous vide lamb and sauce colour were considered too dark compared to the conventional version, although the slightly lower hedonic scores were not significantly different. For Chicken Dijonnaise the factors are less clear although the most important factor is dominated by the two attributes showing significant differences, chicken texture and sauce flavour (Table 11). Again, if the attributes making up Factor 1 are related to the hedonic responses (liking before/after) in Table 11, the sous vide chicken texture was slightly less tender than ideal with the conventional version slightly more tough than ideal. The other attribute in Factor 1, the sous vide sauce flavour was much weaker than ideal, although again the slightly lower hedonic scores were not significantly different. So again, the factor analysis seems to produce meaningful results.

The transformations used for desirability values in this experiment have been linear (Figure 18). If however, these transformations from attribute score (y) to desirability value (d) are non-linear, Harrington (1965) proposed that for two-sided relationships, e.g. the Relative-to-ideal scale, the following equation can be used:-

$$d = e^{-(|y'|)^n}$$

Where, d = desirability value (0 to 1)

n = positive number ($0 < n < \infty$), chosen to reflect the shape of the response curve, the lower the value of n, the more rounded the curve

y' = a linear transformation of the raw data variable, y, so that y' = +1 when $y = y_{max.}$ (upper specification limit for raw data) and y' = -1 when $y = y_{min.}$ (lower specification limit for raw data)

y_i = particular value of y (raw data variable) is transformed by $y_i' = \frac{2y_i - (y_{max} + y_{min})}{y_{max} - y_{min}}$

For the one-sided relationship, Harrington (1965) proposed a special form of the Gompertz growth curve:-

$$d = e^{-(e^{-y'})}$$

Where:- d = desirability value (0 to 1)

y' = a linear transformation of the raw data variable, based on taking two values of raw data, assigning them desirability values, calculating y' from:-

$y' = -[\ln(-\ln d)]$ to give two pairs of y and y' from which b_0 and b_1 in $y' = b_0 + b_1 y$ can be calculated for general values of y.

Possible examples of these non-linear transformation are shown in Figure 21. Using these transformations or changing the points where desirability values of 0 and 1 are fixed (Table 7), would produce different desirability values to those generated in this experiment. This, in turn, could change many of the resulting conclusions. However, the concept of taking data from many types of scale and transforming to a common scale could have potential for comparing results from research which has made use of different sensory evaluation techniques.

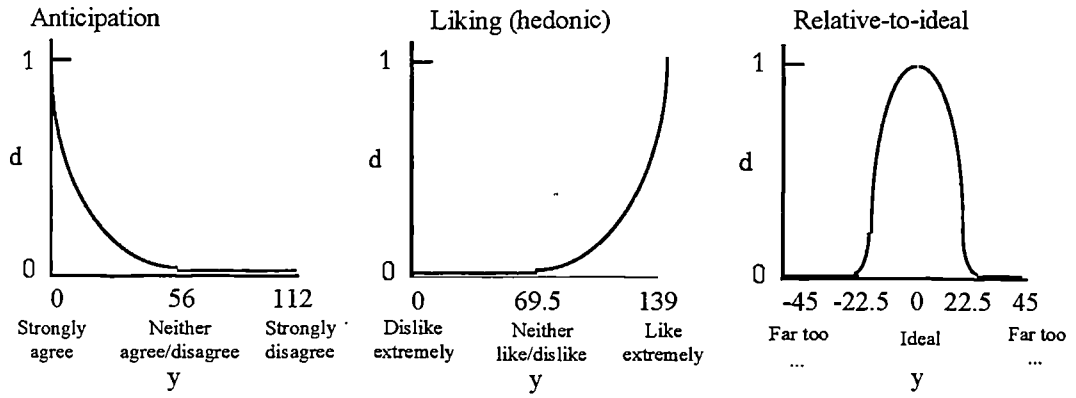


Figure 21. Examples of non-linear transformations from raw data (y) to desirability values (d).

2.2.5 Conclusions from Experiment 2

This experiment has taken place in an ecologically valid environment to test the result of Experiment 1 performed in a scientifically controlled environment on whether sous vide foods are distinguishable from conventionally prepared foods. It has also aimed to determine the contribution of some extrinsic factors, e.g. anticipation of eating at the university restaurant and to allow consumers to assess acceptability after prompting consideration of how close the food approaches their own ideal qualities. Paired comparison tests have shown a decrease in perceived acceptability after attribute assessment, only for the sous vide chicken dish. Analysis of variance has shown significant differences in terms of weaker Dijonnaise sauce flavour, more tender chicken and darker lamb for the sous vide dishes. Factor analysis has also confirmed the two significantly different chicken attributes as important.

Although this experiment has attempted to examine the use of sous vide foods in an ecologically valid environment, again, no evidence has emerged to support claims of its sensory superiority. Indeed there is evidence that the anticipation of visiting the restaurant is in itself a significant factor in the enjoyment of the meal experience. The next stage therefore aims to determine the place of eating out as a pleasurable experience in a range of human activities depending on a range of human attitudes towards expectations about food, how it is produced, the willingness to try new foods and its importance in providing pleasure when eating out.

2.3 Experiment 3 - Determining importance of food in pleasure when eating out.

2.3.1 Introduction

The objectives of the third experiment of the empirical research were to determine the relative importance of food in giving pleasure when eating out, how the pleasure of eating out relates to a range of other human activities and the effects of a range of human attitudes towards expectations about food, how it is produced and the willingness to try new foods.

2.3.2 Materials and methods

Questionnaires were piloted and modified as necessary to remove ambiguity and improve logic and comprehension (Appendix D.3). The first part of the questionnaire incorporated questions on the demographic details of the respondent and their frequency of eating out. This was followed by a series of questions designed to measure the attitudes mentioned above (2.3.1), two new scales were devised, an 'Intolerance index' and a 'Technophobia index' and one existing scale was used to measure food neophobia (Pliner and Hobden 1992). The first of these new scales was intended to measure an individual consumer's willingness to complain when faced with meals having particular deficiencies by assessing the respondent's level of reaction to a given list of problems with a meal, an intolerance index. The list of problems was generated through posing the question - 'What problems cause you to feel dissatisfied with a meal served to you ?'. The list of reactions (numbered 1 to 9 in the box on page 1 of Appendix D.3) were generated by asking to whom indications of satisfaction or dissatisfaction would be directed and what action might then follow. Replies from the pilot study to these two questions were formed into the questions and reactions on page 1 on the questionnaire (Appendix D.3). The following section of the questionnaire aimed to determine attitudes towards the use of technology in newer methods of meal preparation such as cook-chill, cook-freeze and sous vide compared to conventional meal preparation, a technophobia index. The next sections of the questionnaire assessed the respondents' degree of neophobia/neophilia using the Food Neophobia Scale of Pliner and Hobden (1992); and determined which factors are the most important in giving pleasure when eating out using part of a list of variables taken from Reeve *et al.* (unpublished data 1996). Finally, respondents were required to rate a range of activities for derived pleasure using a scale from 'great displeasure' to 'great pleasure', originally proposed by Young (1959) as ranging from 'distress' to 'delight'.

Questionnaires were given to the respondents with a brief explanation that the research was studying attitudes towards eating away from home. Results were collected over a three week period and entered into an Excel spreadsheet and imported into Statview (Abacus Concepts 1992) and SuperANOVA (Abacus Concepts 1993) for analysis. Analysis of variance, Kruskal Wallis (Kruskal and Wallis 1952), contingency, paired comparison and regression tests were used to determine any significant differences in the mean values for intolerance index, technophobia index and Food Neophobia Score between respondents grouped by gender, age, Social Class (SC) and frequency of eating out. Variables showing the relative importance of factors giving pleasure when eating out and the pleasure given by a range of activities were analysed by factor analysis.

2.3.3 Results from Experiment 3

From the survey, 188 completed questionnaires were collected. The demographic details for gender, Social Class and age group are summarised in Table 20 by number and by percentage of the total number of respondents.

The distribution of respondents by gender, age group and Social Class do not appear unbalanced. The numbers in SC I appear high but owing to their influence on the growth in eating out discussed earlier in section 1.1, this would not seem inappropriate.

Table 21 shows the distribution of frequency of eating out against Social Class by number and by percentage of the total number of respondents.

Gender	SC	Age Group up to 19	20-24	25-34	35-44	45-54	55-64	over 65	Missing	Total	Total
Male	I	2 (1)	7 (3.5)	4 (2)	14 (7.5)	18 (10)	5 (2.5)	2 (1)	0 (0)	52 (27.5)	
	II	0 (0)	0 (0)	0 (0)	1 (0.5)	9 (5)	7 (3.5)	2 (1)	0 (0)	19 (10)	
	IIIN	0 (0)	2 (1)	2 (1)	2 (1)	1 (0.5)	0 (0)	2 (1)	0 (0)	9 (5)	105 (56)
	IIIM	1 (0.5)	2 (1)	1 (0.5)	4 (2)	2 (1)	1 (0.5)	1 (0.5)	0 (0)	12 (6)	
	IV	5 (2.5)	1 (0.5)	0 (0)	0 (0)	1 (0.5)	0 (0)	0 (0)	0 (0)	7 (3.5)	
	Missing	1 (0.5)	1 (0.5)	0 (0)	2 (1)	1 (0.5)	1 (0.5)	0 (0)		6 (3)	
	Total	9 (5)	13 (7)	7 (3.5)	23 (12)	32 (17)	14 (7.5)	7 (3.5)	0 (0)		
Female	I	0 (0)	3 (1.5)	5 (2.5)	7 (3.5)	7 (3.5)	1 (0.5)	0 (0)	0 (0)	23 (12)	
	II	1 (0.5)	1 (0.5)	2 (1)	6 (3)	6 (3)	1 (0.5)	2 (1)	0 (0)	19 (10)	
	IIIN	0 (0)	3 (1.5)	1 (0.5)	0 (0)	10 (5)	2 (1)	4 (2)	1 (0.5)	21 (11)	83 (44)
	IIIM	0 (0)	2 (1)	2 (1)	0 (0)	1 (0.5)	1 (0.5)	0 (0)	0 (0)	6 (3)	
	IV	5 (2.5)	1 (0.5)	1 (0.5)	0 (0)	0 (0)	3 (1.5)	0 (0)	0 (0)	10 (5)	
	Missing	0 (0)	1 (0.5)	1 (0.5)	0 (0)	1 (0.5)	1 (0.5)	0 (0)		4 (2)	
	Total	6 (3)	11 (6)	12 (6)	13 (7)	25 (13)	9 (5)	6 (3)	1 (0.5)		
	Total	15 (8)	24 (13)	19 (10)	36 (19)	57 (30)	23 (12)	13 (7)	1 (0.5)		188 (100)

Table 20. Distribution of respondents by gender, Social Class (SC) and age group. Percentage figures in parentheses may not add up to given totals due to rounding.

SC	Frequency of eating out: Most days/twice weekly	At least once a week	Fort-nightly	At least once a month	Less often	Missing	Total
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
I	14 ¶ (7)	15 (8)	16 (9)	15 (8)	14 (7.5)	1 (0.5)	75 (40)
II	4 (2)	8 (4)	1† (0.5)	10 (5)	14 ¶ (7.5)	1 (0.5)	38 (20)
IIIN	0 † (0)	6) (3	3 (1.5)	8 (4)	11 (6)	2 (1)	30 (16)
IIIM	4 (2)	4 (2)	3 (1.5)	5 (2.5)	1 (0.5)	1 (0.5)	18 (10)
IV	0 (0)	1 (0.5)	7 ¶ (3.5)	5 (2.5)	3 (1.5)	1 (0.5)	17 (9)
Miss-ing	0 (0)	4 (2)	0 (0)	2 (1)	3 (1.5)	1* (0.5)	10 (5)
Total	22 (12)	38 (20)	30 (16)	45 (24)	46 (24.5)	7 (3.5)	188 (100)

Table 21. Distribution of respondents by Social Class (SC) and frequency of eating out (* 1 male gave neither occupation or eating frequency). Cells marked ¶, are significantly higher than expected ($p<0.05$) and those marked †, significantly lower than expected ($p<0.05$). Percentage figures in parentheses may not add up to given totals due to rounding.

A contingency table with χ^2 test showed that some cell numbers were significantly higher or lower than expected ($p<0.05$). As an example, five more respondents than expected from SC I ate out 'Most days/ twice weekly'. The expected value for this cell is calculated from the product of the column total (22) and row total (75) divided by the grand total (188) or 22 x 75 / 188 = 8.77 or 9 compared to the observed value of 14. To check whether these differences are significant, the Statview program gives a table of *post hoc* cell contributions. These are standardised residuals indicating what each cell contributes to the overall χ^2 statistic, calculated to follow a normal distribution. This means that, for example, an absolute value greater than 1.96 indicates a significant difference ($p<0.05$). For Social Class against frequency of eating out, the Statview program produces Table 22.

		Frequency of eating out: 1	2	3	4	5
Social Class	I	2.091	.144	1.255	-1.245	-1.600
	II	-.407	.320	-2.667	.321	2.036
	III N	-2.215	.241	-1.025	.477	1.908
	III M	1.397	.410	.023	.443	-1.918
	IV	-1.609	-1.426	2.912	.606	-.606

Table 22. Post hoc contributions from contingency table of number of respondents by Social Class (SC) against frequency of eating out.

Columns 1 to 5 in Table 22 indicate eating frequency from 'Most days/twice weekly' to 'Less often'. Those cell values greater than + 1.96 indicate a cell number significantly higher than expected, those less than - 1.96 indicate a cell number significantly lower than expected. The cell for the example quoted above is 2.091 so the observed number in this cell of 14 is significantly higher ($p<0.05$) than the number expected of 9.

Age group	Frequency of eating out: Most days/twice weekly	At least once a week	Fort-nightly	At least once a month	Less often	Miss-ing	Total
	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)	No. (%)
up to 19	0 (0)	2 (1)	4 (2)	6 (3)	3 (1.5)	0 (0)	15 (8)
20-24	1 (0.5)	4 (2)	8 ¶ (4)	5 (2.5)	4 (2)	2 (1)	24 (13)
25-34	6 ¶ (3)	4 (2)	4 (2)	4 (2)	1 † (0.5)	0 (0)	19 (10)
35-44	5 (2.5)	6 (3)	7 (3.5)	5 (2.5)	12 (6)	1 (0.5)	36 (19)
45-54	5 (2.5)	11 (6)	5 (2.5)	17 (9)	17 (9)	2 (1)	57 (30)
55-64	5 (2.5)	6 (3)	1 (0.5)	5 (2.5)	5 (4)	1 (0.5)	23 (12)
over 65	0 (0)	5 (2.5)	1 (0.5)	3 (1.5)	4 (2)	0 (0)	13 (7)
Miss-ing	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1* (0.5)	1 (0.5)
Total	22 (12)	38 (20)	30 (16)	45 (24)	46 (24.5)	7 (3.5)	188 (100)

Table 23. Distribution of respondents by age group and frequency of eating out (* 1 female gave neither age group or eating frequency). Cells marked ¶, are significantly higher than expected ($p<0.05$) and those marked †, significantly lower than expected ($p<0.05$). Percentage figures may not add up to given totals due to rounding.

Table 23 shows the distribution of frequency of eating out against age group by number and by percentage of the total number of respondents.

A contingency table with χ^2 test showed that some cell numbers were significantly higher or lower than expected ($p<0.05$). As an example, three more respondents than expected from the 25 to 34 age group ate out 'Most days/ twice weekly'.

The data from the questions for assessing the intolerance index for an individual, i.e. their likelihood of complaining about certain types of problems with a meal are summarised in Figure 22.

It is clear that the problem of poor acceptability of a meal has the most consistent response. The distributions most skewed towards the low end come from problems of poor presentation and over-generous portions. Although the intolerance levels are ranks rather than continuous variables, the mean values for individuals (The Intolerance Index) give some indication of their intolerance towards food problems, a low score indicating tolerance and a high score, intolerance to problems with meals.

The data were also analysed with respect to whether the meal would be finished (responses of 1, 2, 4 and 6) or not (responses of 3, 5, 7, 8, and 9). For this purpose, responses 1, 2, 4 and 6 were given values of 1, 2, 3, and 4 respectively for the index where the meal would be finished and responses 3, 5, 7, 8 and 9 were given values 1, 2, 3, 4 and 5 where the meal would not be finished. From this, for each respondent two more indices were calculated based on the average, ignoring missing values. As these scales have ranges from 1 to 4 and 1 to 5 compared to the original 1 to 9 for all types of response, the mean values were adjusted according to the scale lengths to equate to the 1 to 9 scale length. Table 24 shows for each meal problem the number of responses in each category, finishing or not finishing the meal.

The problems where meals were most likely to be finished were, in order, poor presentation, too little, balance and too much. Those most likely to lead to unfinished meals were, in order, poor acceptability, wrong type of food, wrong temperature, personal requirements and seasoning. The response to a meal not being cooked as expected was more evenly divided.

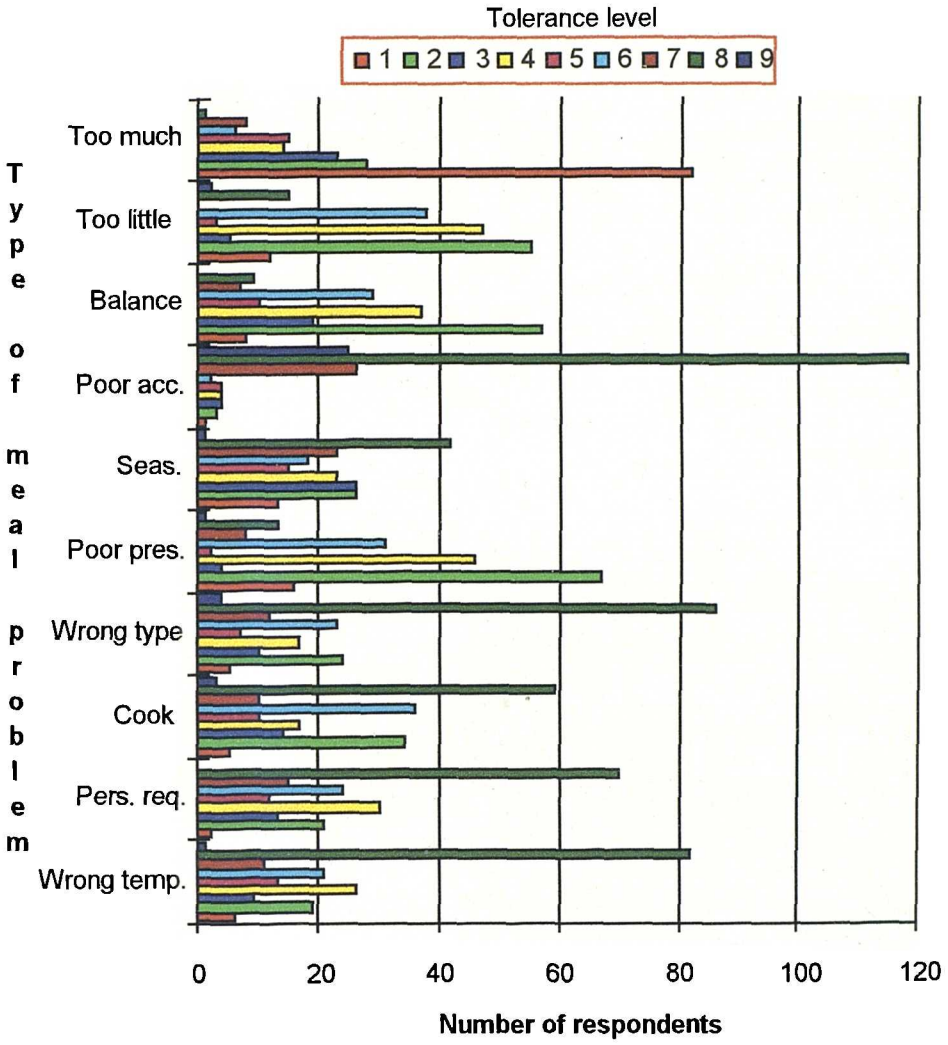


Figure 22. Distribution of intolerance levels for each meal problem. (Details on Type of meal problem and Intolerance levels in Appendix D.3).

Meal Problem	Finished meal responses					Unfinished meal responses						
	1	2	4	6	Total	3	5	7	8	9	Total	Miss-ing
Too much	82	28	14	6	130	23	15	8	1	0	47	11
Too little	12	55	47	38	152	5	3	0	15	2	25	11
Balance	8	57	37	29	131	19	10	7	9	0	45	12
Poor acceptability	1	3	4	2	10	4	4	26	118	25	177	1
Seasoning	13	26	23	18	80	26	15	23	42	1	107	1
Poor presentation	16	67	46	31	160	4	2	8	13	1	28	0
Wrong type	5	24	17	23	69	10	7	12	86	4	119	0
Cooking	5	34	17	36	92	14	10	10	59	3	96	0
Personal requirements	2	22	30	24	78	13	12	15	70	0	110	0
Wrong temperature	6	19	26	21	72	9	13	11	82	1	116	0

Table 24. Distribution of finished and unfinished meal responses against type of meal problem (n=188).

Parametric analysis of variance would not be applicable to this type of data so the non-parametric equivalent of the one-way ANOVA, the Kruskal Wallis test, was used to determine any effect of age group, frequency of eating out and Social Class on the intolerance index for all responses, for finished and for unfinished meal responses (Tables 25, 26, 27). In the Kruskal Wallis test, the equivalent of the One Way Analysis of Variance for non-parametric data, all individual intolerance indices are ranked, subdivided by age group, frequency of eating out or Social Class and then averaged to give the mean ranks (allowing for tied values) shown in Table 25, 26 and 27.

The mean intolerance indices generally show a tendency to rise as age increases (Table 25). For all responses the mean rank values are consistent with the mean intolerance indices showing the effect that intolerance to meal problems grows with increasing age, i.e. the mean rank from the '55 to 64' age group is significantly higher than that from the 'up to 19' age group. There are apparently no *post hoc* tests equivalent to those for parametric data so this conclusion that the highest mean rank is significantly different from the lowest mean rank is all that can be concluded in this case. Dividing the responses according to whether the meal would be finished or not produced slightly different patterns. For the finished meal response no mean ranks were significantly different using the traditional $p = 0.05$ criterion but for unfinished meal responses, the mean rank from the '55 to 64' age group was significantly higher

than that from the 'up to 19' age group, the same pattern as shown above for all responses.

Age Group	up to 19	20-24	25-34	35-44	45-54	55-64	over 65
Number	15	24	19	36	57	23	13
Mean intolerance index (all responses)	4.007	4.288	4.757	5.283	5.239	5.586	5.372
Mean rank (H = 26.97, p = 0.0001)	48.57a	63.48	82.84	103.25	105.25	116.41b	104.50
Mean intolerance index (Finished meal responses)	4.494	4.863	5.065	5.836	5.444	5.601	6.568
Mean rank H = 11.512, p = 0.074)	65.83	77.21	83.45	105.46	95.24	97.00	119.04
Mean intolerance index (Unfinished meal responses)	4.186	5.605	5.310	5.541	5.632	6.238	4.967
Mean rank H = 13.789, p = 0.032)	55.70a	97.71	90.95	94.32	96.36	117.65b	75.77

Table 25. Effect of age group on intolerance index and mean rank for all, for finished meal and unfinished meal responses, n = 187. Mean ranks with different letters are significantly different at probability level shown.

Frequency of eating out	Most days/twice weekly	At least once a week	Fort-nightly	At least once a month	Less often
Number	22	38	30	45	46
Mean intolerance index (all responses)	5.106	5.726	4.715	4.730	4.994
Mean rank (H = 13.091, p = 0.0108)	91.80	116.13a	76.73b	79.66	90.26
Mean intolerance index (Finished meal responses)	5.241	6.380	5.435	5.084	5.208
Mean rank H = 8.856, p = 0.0648)	84.32	112.12	88.82	81.59	83.79
Mean intolerance index (Unfinished meal responses)	5.652	5.790	5.055	5.485	5.326
Mean rank H = 4.033, p = 0.4015)	95.75	101.53	79.12	92.42	84.47

Table 26. Effect of frequency of eating out on intolerance index and mean rank for all, for finished meal and unfinished meal responses, n = 181. Mean ranks with different letters are significantly different at probability level shown.

Testing for all responses against frequency of eating out (Table 26) showed a significant difference with the 'At least once a week' group being more intolerant than the 'Fortnightly' group (p = 0.0108). However, the statistics for finished and

unfinished meal responses, (p = 0.0648) and H = 4.033 (p = 0.4015) respectively, showed no significant differences between mean ranks.

Testing for all responses against Social Class (Table 27) produced a significant difference where the mean rank for SC I was higher than SC IV (p = 0.0328). The statistics for finished meal responses against Social Class, (p = 0.0238) showed that again the mean rank for SC I was significantly higher than that for SC IV. The equivalent for unfinished meal responses, (p = 0.182), showed no significant differences between mean ranks.

Social Class	I	II	IIIN	IIIM	IV
Number	75	37	30	18	17
Mean intolerance index (all responses)	5.236	4.892	4.991	5.141	4.147
Mean rank (H = 10.50, p = 0.0328)	98.33a	85.79	96.06	87.93	54.67b
Mean intolerance index (Finished meal responses)	5.949	5.170	4.952	5.507	4.596
Mean rank H = 11.264, p = 0.0238)	102.16a	80.26	90.11	77.17	65.27b
Mean intolerance index (Unfinished meal responses)	5.636	5.419	5.347	5.944	4.534
Mean rank H = 6.244, p = 0.182)	94.46	85.68	101.61	86.05	64.00

Table 27. Effect of Social Class on intolerance index and mean rank for all, for finished meal and unfinished meal responses, n = 177. Mean ranks with different letters are significantly different at probability level shown.

The correlation (n = 185) between the intolerance index from all responses and those for finished meals was 0.672 ($p<0.001$) and for unfinished meals was 0.521 ($p<0.0001$). The correlation between indices for finished and unfinished meals was 0.136 (p = 0.064).

The questions on attitudes towards methods of meal production were analysed. Using analysis of variance, no significant effects ($p>0.05$) were found for gender, age, eating frequency and Social Class in level of agreement towards the statement, 'The way my meal is prepared is important to me'. The mean values are shown in the column 'Attitudes to methods' (Table 28). The responses to the acceptability of six methods of food preparation were also analysed and the mean values shown in columns labelled 1 to 6 (Table 28). For each respondent, the average of the five non-conventional methods (2 to 6) was expressed as a percentage of that individual's rating for the conventional method to give an index. The averages for each group are shown in the column 'Technophobia Index' (Table 28).

Table 28 shows few significant differences ($p<0.05$) between means except for females considering dehydrated food as significantly less acceptable than men, the

20 to 24 age group finding cook-chill food significantly more acceptable than the over 65 age group, those in SC I finding sous vide preparation significantly more acceptable than SC IIIM and cook-chill significantly more acceptable than SC II. There was a tendency for the over 65 age group to perceive any method other than conventional preparation as less acceptable. There was also a tendency for the acceptability of new methods of meal preparation to decline with Social Class from I to IV.

		Atti-tude to method	1 Conven-tional	2 Cook-freeze	3 Cook-chill	4 Sous vide	5 Dried	6 Mixed	Techno-phobia Index
Gender	Male	87.95	128.00	80.54	71.50	75.68	57.57a	66.04	56.48
	Female	89.87	129.42	83.16	70.35	66.43	40.95b	61.07	50.05
Age Group	up to 19	78.15	126.13	74.87	73.2	49.00	39.73	48.07	45.70
	20-24	87.43	124.63	88.58	93.92a	78.38	56.17	82.42	65.29
	25-34	96.80	124.26	82.33	72.42	67.53	50.42	67.21	56.03
	35-44	86.74	132.06	91.03	79.64	76.39	46.06	65.89	55.23
	45-54	91.79	126.48	78.09	61.16	70.77	52.60	61.12	52.18
	55-64	94.39	134.39	82.96	71.65	78.91	65.52	70.44	55.49
	65 +	80.00	134.08	59.46	36.85b	63.39	23.85	37.08	34.14
Frequ-ency of eating out	Most days / twice weekly	87.43	129.68	80.91	68.73	81.59	64.59	73.09	57.55
	At least once a week	96.29	126.58	77.11	66.55	72.95	50.40	63.63	54.44
	Fort-nightly	89.00	127.47	93.03	80.17	71.40	46.80	68.27	57.04
	At least once a month	84.95	129.60	85.07	74.51	68.07	47.16	58.07	52.12
	Less often	86.76	128.58	76.00	68.28	69.35	50.02	63.46	51.60
SC	I	88.25	128.83	88.45	86.21a	86.45a	60.16	75.37	62.37
	II	86.76	128.97	75.11	58.71b	66.58	54.18	61.53	50.44
	IIIN	94.72	127.93	89.23	62.37	67.83	39.89	60.73	44.26
	IIIM	89.83	126.83	65.29	52.61	54.44b	47.33	52.89	51.56
	IV	85.86	126.44	78.00	71.88	55.18	28.71	45.65	44.70

Table 28. Mean values of attitude to method of meal preparation and of perceived acceptability of six methods of meal preparation according to gender, age group, frequency of eating out and Social Class (SC). For attitude to methods column, 0 = Strongly disagree, 112 = strongly agree; for columns 1 to 6, 0 = Totally unacceptable to 138 = Totally acceptable. (Means in the same column within the same box bearing subscripts with different letters are significantly different, $p<0.05$).

Scores from the Food Neophobia Scale (FNS) were examined to determine any differences due to gender, age, eating frequency and Social Class. The mean values of FNS are shown in Table 29. These scores increase with food neophobia from a minimum possible value of 10 to a maximum possible value of 70.

The main significant differences were that the over 65 age group was more neophobic than the 25 to 34 age group ($p<0.05$), the least frequent eaters out were more neophobic than the most frequent eaters out ($p<0.05$) and SC I was less

neophobic than both SC II and IIIM. Trends also indicate that neophobia increases with age and with decreasing frequency of eating out.

Effect		FNS	S.D.	S.E.	No.
Gender	Male	29.45	12.53	1.22	105
	Female	28.68	11.32	1.24	83
Age Group	up to 19	32.27	10.18	2.63	15
	20-24	31.88	10.87	2.22	24
	25-34	21.26a	8.27	1.90	19
	35-44	26.53	13.15	2.19	36
	45-54	27.65	11.20	1.48	57
	55-64	33.13	11.99	2.50	23
	65 +	37.54b	12.80	3.55	13
Frequency of eating out	Most days/ twice weekly	20.27a	8.05	1.71	22
	At least once a week	26.76	10.35	1.68	38
	Fortnightly	29.10	11.24	2.06	30
	At least once a month	29.11	12.61	1.88	45
	Less often	33.85b	12.50	1.84	46
SC	I	24.48a	10.88	1.25	75
	II	32.34b	11.21	1.82	38
	IIIN	31.17	11.17	2.04	30
	IIIM	29.06	14.76	3.48	18
	IV	36.12b	11.63	2.82	17

Table 29. Mean values of Food Neophobia Scores (FNS) according to gender, age group, frequency of eating out and Social Class (SC). (Means in the same column within the same box bearing subscripts with different letters are significantly different, $p<0.05$).

In addition to the specific ten attitudinal statements suggested by Pliner and Hobden (1992) for their Food Neophobia Score (FNS), an extra question was added - 'When eating out, I will try a new food'. This was added because it was suggested during pre-testing the questionnaire that the concept of a dinner party in the seventh FNS statement (Appendix D.3) could be outside the frame of reference of many respondents. The response to this added statement was substituted for the FNS seventh statement to give a Modified Food Neophobia Score (MFNS). A paired comparison showed that the mean difference (0.372) between the two scores was significantly different from zero ($p = 0.0006$) and the correlation between them was 0.993. The mean values of MFNS are shown in Table 30 where scores increase with food neophobia from a minimum value of 10 to a maximum value of 70. The FNS and MFNS analyses of variance in Tables 29 and 30 produced the same pattern of significant differences.

Effect		MFNS	S.D.	S.E.	No.
Gender	Male	29.68	12.80	1.25	105
	Female	29.23	11.63	1.28	83
Age Group	up to 19	33.13	10.74	2.77	15
	20-24	32.50	11.83	2.41	24
	25-34	21.21a	8.60	1.97	19
	35-44	26.86	13.23	2.21	36
	45-54	27.88	11.22	1.49	57
	55-64	33.78	12.56	2.62	23
	65 +	37.77b	12.42	3.45	13
Frequency of eating out	Most days/ twice weekly	20.63a	8.24	1.76	22
	At least once a week	26.61	10.70	1.74	38
	Fortnightly	29.90	11.90	2.17	30
	At least once a month	29.53	12.85	1.92	45
	Less often	34.48b	12.54	1.85	46
SC	I	24.92a	11.10	1.28	75
	II	32.66b	11.35	1.84	38
	IIIN	31.47	11.37	2.08	30
	IIIM	28.78	14.83	3.50	18
	IV	36.94b	12.79	3.10	17

Table 30. Mean values of Modified Food Neophobia Scores (MFNS) according to gender, age group, frequency of eating out and Social Class (SC). (Means in the same column within the same box bearing subscripts with different letters are significantly different, $p<0.05$).

The mean values of the responses to the 33 variables which could possibly influence pleasure when eating out are shown in ascending order (Table 31) with details on significant differences between mean values (Table 32). The complete data matrix was analysed by factor analysis to explore its structure and to reduce the data to a smaller number of factors which together could elucidate what is important to consumers when eating out.

The factor analysis produced 13 factors from the 33 variables used which accounted for 75.4 % of the variance (Table 33). During the procedure, attributes which contained no factor loading greater than 0.500 were deleted from the analysis until all attributes in the final solution loaded at this value on at least one factor. Thereafter, the criterion for selection was based on the number of samples (Hair *et al.* 1995) resulting in a value of 0.425 for significance ($p<0.05$). The complete oblique solution primary pattern matrices with summary tables and Eigen values are shown in Appendix E.2.

Variable	Mean	S.D.	S.E.	Coeff. Var.	Count	Missing
Live entertainment	1.770	1.045	0.076	0.590	187	1
Presence of children	1.973	1.104	0.081	0.560	187	1
Presence of recorded music	1.979	1.097	0.080	0.555	187	1
Facilities for children	2.326	1.318	0.096	0.567	187	1
Formality of the meal occasion	2.349	1.081	0.079	0.460	186	2
Vegetarian /vegan menu	2.380	1.407	0.103	0.591	187	1
What you wear	2.412	1.071	0.078	0.444	187	1
Facilities for disabled	2.417	1.465	0.107	0.606	187	1
The other customers	2.583	0.977	0.071	0.378	187	1
Location of the restaurant	2.674	1.019	0.075	0.381	187	1
The farewell from staff	2.722	1.106	0.081	0.406	187	1
Layout of items on table	2.749	1.035	0.076	0.376	187	1
Staff dress	2.824	1.076	0.079	0.381	187	1
Range of drinks available	2.995	1.201	0.088	0.401	186	2
Privacy of your seating	3.011	1.097	0.080	0.364	187	1
Availability of alcohol	3.075	1.318	0.096	0.429	187	1
Decor/lighting of dining room	3.187	0.881	0.064	0.277	187	1
Type of meal service	3.214	1.056	0.077	0.329	187	1
Language of the menu	3.225	1.165	0.085	0.361	187	1
Welcome given by staff	3.257	1.031	0.075	0.317	187	1
Attractiveness of menu	3.280	0.996	0.073	0.304	186	2
Help from staff when ordering	3.294	1.099	0.080	0.334	187	1
Mood created in dining room	3.358	0.852	0.062	0.254	187	1
Attentive staff during meal	3.387	1.035	0.076	0.306	186	2
Range of menu items	3.417	0.937	0.069	0.264	187	1
Time to relax at end of meal	3.444	0.995	0.073	0.289	187	1
Overall cost of the occasion	3.529	1.069	0.078	0.303	187	1
Comfort of seats	3.594	0.889	0.065	0.247	187	1
Information given on menu	3.615	0.951	0.070	0.263	187	1
Enjoyment of wine	3.642	1.272	0.093	0.349	187	1
Friendliness of staff	3.786	0.890	0.065	0.235	187	1
Appearance of the meal	3.823	0.822	0.060	0.215	186	2
Enjoyment of food	4.492	0.617	0.045	0.137	187	1

Table 31. Summary of mean values in ascending order on importance of variables giving pleasure when eating out (1 = Not important, 2 = Slightly important, 3 = Moderately important, 4 = Very important, 5 = Extremely important).

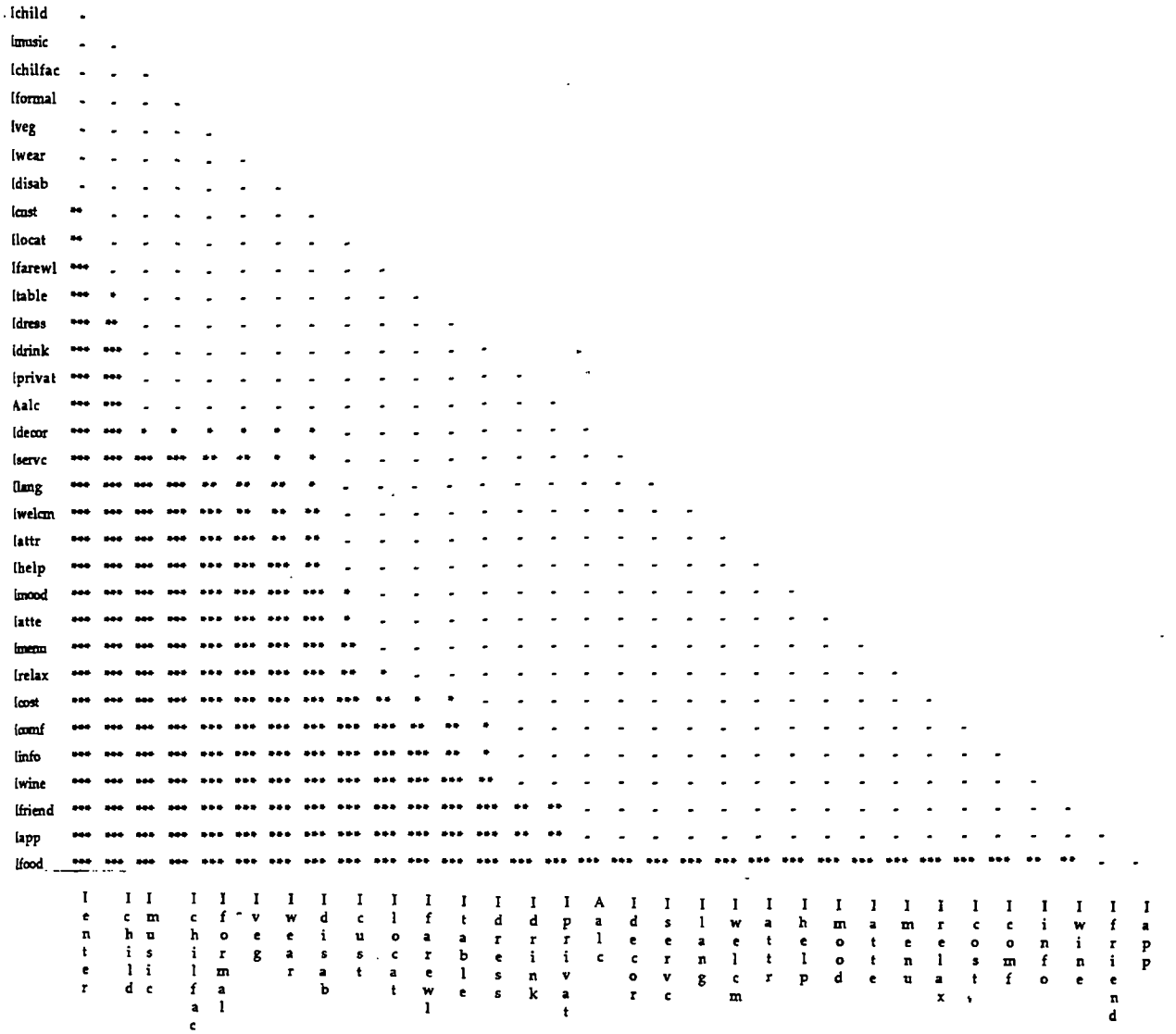


Table 32. Significant differences between mean values of variables in Table 31 (- = not significant, * = $p<0.05$, ** = $p<0.01$, *** = $p<0.001$).

	Attribute	Factor loading	Labels
Factor 1	Welcome from staff	0.858	Customer care
V.E. = 26.1%	Friendliness of staff	0.810	
	Help from staff	0.780	
	Attentive staff	0.778	
	Farewell from staff	0.769	
	Disabled facilities	0.603	
Factor 2	Availability of alcohol	0.902	Drink
V.E. = 8.5%	Enjoyment of wine	0.790	
	Range of drinks	0.775	
Factor 3	Live entertainment	0.790	Entertainment
V.E. = 6.3%	Recorded music	0.704	
Factor 4	Other customers	0.761	Formality of
V.E. = 5.8%	What you wear	0.745	occasion
	Staff dress	0.585	
	Table layout	0.553	
	Formality of the meal	0.456	
	Time to relax at end of meal	0.426	
Factor 5	Privacy of seating	0.813	Ambience
V.E. = 5.0%	Decor/lighting	0.710	
	Comfort of seats	0.502	
Factor 6	Vegetarian/vegan menu	0.917	Vegetarian
V.E. = 4.1%			
Factor 7	Location of restaurant	0.828	Atmosphere
V.E. = 3.7%	Mood created in dining room	0.715	
Factor 8	Presence of children	0.822	Children
V.E. = 3.4%			
Factor 9	Language of menu	0.848	Menu presentation
V.E. = 3.4%	Information on menu	0.669	vs. other customers
	Other customers	-0.500	
Factor 10	Overall cost of the occasion	0.749	Cost vs. occasion
V.E. = 3.2%	Formality of the meal	-0.527	
Factor 11	Appearance of the meal	0.635	Food
V.E. = 2.9%	Enjoyment of food	0.616	
Factor 12	Type of meal service	0.689	Service
V.E. = 2.8%			

Table 33. Factors from factor analysis of importance of attributes in giving pleasure when eating out (n=183) (V.E. = variance explained).

The factors contained variables which combined well, enabling them to be labelled fairly concisely from 'Customer care' as the most important factor accounting for 26.1 % of variance through to Factor 11 'Food', accounting for just 2.9 % of variance. It should be noted that the mean values for the variables in Table 31 need to be examined to determine whether the variable is considered of low or high importance. For example, in Factor 3, both variables have low mean scores so this factor is important because responses showed a consistency in considering that both live entertainment and the presence of recorded music were of low importance in giving then pleasure when eating out. The data was also split by gender, high and low frequency eaters and old and young age groups. Similar patterns emerged with only minor changes in the factor structures.

The mean values of the levels of pleasure derived from 29 activities are shown in ascending order (Table 34) with details on significant differences between mean values (Table 35). The complete data matrix was also analysed by factor analysis to explore its structure and to reduce the data to a smaller number of factors which together could elucidate what how much pleasure is derived from a range of activities. The procedure for data reduction was the same as for the previous factor analysis.

Activity	Mean	S.D.	S.E.	Coeff. Var.	Count	Miss-ing
Smoking - cigarettes, pipe, cigars, etc.	16.303	23.537	1.730	1.444	185	3
Gambling - Lottery, horse racing, etc.	16.962	18.283	1.341	1.078	186	2
Playing computer games	22.242	19.435	1.425	0.874	186	2
Collecting antiques, stamps, etc.	23.797	19.944	1.458	0.838	187	1
Making music - keyboards, strings, etc.	27.151	19.338	1.422	0.712	186	2
Doing nothing	28.306	22.337	1.638	0.789	186	2
Driving or maintaining cars	30.774	19.158	1.405	0.623	186	2
Home maintenance & improvements	31.984	21.458	1.569	0.671	187	1
Watching sport as a spectator	37.762	19.973	1.468	0.529	185	3
Working for charity	37.863	18.169	1.343	0.480	183	5
Drawing, painting, crafts, etc.	37.925	17.473	1.278	0.461	187	1
Participating in sports	38.663	22.419	1.653	0.580	184	4
Sleeping or dozing	41.602	17.793	1.323	0.428	181	7
Watching television	41.734	16.306	1.202	0.391	184	4
Cooking for self, family or friends	41.882	20.574	1.505	0.491	187	1
Working for money	43.033	16.244	1.201	0.377	183	5
Going out for a drink at pubs, clubs, etc.	43.430	18.401	1.349	0.424	186	2
Having a drink at home	44.301	15.878	1.164	0.358	186	2
Walking, rambling, etc.	45.129	17.985	1.319	0.399	186	2
Reading books, magazines, etc.	49.043	14.930	1.092	0.304	185	3
Listening to music - CDs/records/tapes	49.500	15.812	1.159	0.319	186	2
Eating a meal at home	49.616	12.326	0.906	0.248	185	3
Going to films, theatre, concerts, etc.	50.346	14.755	1.085	0.293	185	3
Doing things with the family	51.032	15.636	1.147	0.306	186	2
Eating out at a restaurant, hotel, etc.	52.804	12.220	0.901	0.231	184	4
Sexual activity	53.202	15.288	1.162	0.287	173	15
Holidays away from home	53.513	14.213	1.039	0.266	187	1
Travelling to new places	55.551	10.863	0.799	0.196	185	3
Doing things with friends	55.591	11.451	0.840	0.206	186	2

Table 34. Summary of mean values on levels of pleasure for a range of activities in ascending order (0 = Great displeasure, 32 = Indifferent, 64 = Great pleasure).

	Asmoke	Agamb	Acomp	Acollect	Aplmus	Anothng	Acars	Ahome	Awsprt	Awchar	Adraw	Asport	Asleep	Awtv	Acook	Awmoney	Adrnkout	Adrnkhm	Awalk	Aread	Alismus	Aeathm	Afilms	Afamly	Aeatout	Asex	Aholid	Atrav
Agamb	-																											
Acomp	-	-																										
Acollect	-	-	-																									
Aplmus	-	-	-	-																								
Anothng	*	-	-	-	-																							
Acars	***	**	-	-	-	-																						
Ahome	***	***	-	-	-	-	-																					
Awsprt	***	***	***	***	-	-	-	-																				
Awchar	***	***	***	***	-	-	-	-	-																			
Adraw	***	***	***	***	-	-	-	-	-	-																		
Asport	***	***	***	***	-	-	-	-	-	-	-																	
Asleep	***	***	***	***	***	**	-	-	-	-	-	-																
Awtv	***	***	***	***	***	**	-	-	-	-	-	-	-															
Acook	***	***	***	***	***	**	-	-	-	-	-	-	-	-														
Awmoney	***	***	***	***	***	***	*	-	-	-	-	-	-	-	-													
Adrnkout	***	***	***	***	***	***	*	-	-	-	-	-	-	-	-	-												
Adrnkhm	***	***	***	***	***	***	**	*	-	-	-	-	-	-	-	-	-											
Awalk	***	***	***	***	***	***	***	**	-	-	-	-	-	-	-	-	-	-										
Aread	***	***	***	***	***	***	**	***	-	-	-	-	-	-	-	-	-	-	-									
Alismus	***	***	***	***	***	***	***	***	-	-	-	-	-	-	-	-	-	-	-	-								
Aeathm	***	***	***	***	***	***	***	***	*	-	-	-	-	-	-	-	-	-	-	-	-							
Afilms	***	***	***	***	***	***	***	***	*	*	*	-	-	-	-	-	-	-	-	-	-	-						
Afamly	***	***	***	***	***	***	***	***	**	**	**	*	-	-	-	-	-	-	-	-	-	-	-					
Aeatout	***	***	***	***	***	***	***	***	***	***	***	***	-	-	-	-	-	-	-	-	-	-	-	-				
Asex	***	***	***	***	***	***	***	***	***	***	***	***	-	-	-	-	-	-	-	-	-	-	-	-	-			
Aholid	***	***	***	***	***	***	***	***	***	***	***	***	*	*	-	-	-	-	-	-	-	-	-	-	-	-		
Atrav	***	***	***	***	***	***	***	***	***	***	***	***	***	**	**	**	*	-	-	-	-	-	-	-	-	-	-	
Afriend	***	***	***	***	***	***	***	***	***	***	***	***	***	***	**	**	*	-	-	-	-	-	-	-	-	-	-	-

Table 35. Significant differences between mean values of variables in Table 34 (- = not significant, * = p<0.05, ** = p<0.01, *** = p<0.001)

The factor analysis produced 11 factors from the 29 variables used which accounted for 76.6 % of the variance (Table 36). The method of data reduction was similar to the previous factor analysis. The complete oblique solution primary pattern matrices with summary tables and Eigen values are shown in Appendix E.3.

	Activity	Factor loading	Labels
Factor 1	Gambling, etc.	0.802	Indoors vs.
V.E. = 17.2%	Playing computer games	0.719	outdoors
	Walking, rambling	-0.550	
Factor 2	Holidays away from home	0.905	Travel
V.E. = 11.5%	Travelling to new places	0.830	
Factor 3	Home maintenance	0.880	Home
V.E. = 9.4%	Cooking for self, family, etc	0.647	
	Walking, rambling	0.458	
Factor 4	Sleeping or dozing	0.847	Rest
V.E. = 7.1%	Doing nothing	0.799	
Factor 5	Doing things with friends	0.785	Social eating
V.E. = 6.0%	Eating out	0.812	
Factor 6	Drinking at home	0.882	Drinking & eating
V.E. = 5.6%	Going out for a drink	0.621	
	Eating at home	0.567	
Factor 7	Working for charity	0.821	Pastimes
V.E. = 4.7%	Reading	0.543	
	Making music	0.469	
Factor 8	Driving , maintaining cars	0.853	Cars
V.E. = 4.1%			
Factor 9	Working for money	0.843	Earning vs. leisure
V.E. = 4.0%	Making music	-0.516	
Factor 10	Watching sport	0.749	Sport
V.E. = 3.6%	Participating in sport	0.735	
Factor 11	Listening to music	0.874	The arts
V.E. = 3.4%	Going to films, theatre	0.623	

Table 36. Factors from factor analysis of levels of pleasure given by a range of activities (n=165) (V.E. = variance explained).

The factors from this analysis also contained variables which combined well, enabling the factors to be labelled fairly concisely from 'Indoors vs. outdoors' as the most important factor accounting for 17.2 % of variance through to Factor 5 'Social eating', accounting for 6 % of variance. Again, it should be noted that the mean values for the variables in Table 34 need to be examined to determine whether the variable is considered of low or high importance. For example, in Factor 2, both

variables have high mean scores so this factor is important because responses showed a consistency in stating that travelling and holidays give pleasure to the respondents. In Factor 1, the two significant positive variables have low mean scores for giving pleasure and the negative variable has a higher mean score for giving pleasure. The factor analysis is thus implying that respondents who derive pleasure from gambling and computer games are separated from those who derive pleasure from walking etc. Hence the indoors/outdoors label for this contrast.

2.3.4 Discussion of results from Experiment 3

The demographic distribution of respondents was wide, giving the results of the survey analysis a greater validity and wider range of application for its conclusions. Tendencies for older people to be less tolerant to problems with meals and more suspicious of newer methods of meal preparation than younger people have been shown. The mean Intolerance Index increased (Table 25) and the perceived acceptability as measured by the Technophobia Index decreased with age group (Table 28). The meal problem showing the greatest and most consistent level of intolerance was unacceptable food (Figure 22). This emphasises most clearly that unless the food is acceptable, the other problems become almost insignificant. Dividing the responses according to whether the meal would be finished or not produced similar patterns with age group and Social Class.

Conventionally cooked meals were consistently considered to be more acceptable than all other methods of meal preparation for all demographic groups. The Food Neophobia scores again support the view that suspicion of new foods increases with age.

Perhaps the most prominent findings to emerge from the results are the structures found with the two factor analyses. The first, on the importance of a range of variables in giving pleasure when eating out, has provided some convincing support to the ideas proposed in section 1.4.6. This suggested that the consumer has very different priorities to the chef and sensory analyst on the place of food in the many variables present when eating out. This survey has shown that a group of variables in a factor labelled 'customer care' are strongly associated and have a dominant role in the data structure (Table 33). The least important factors also provided combinations which could easily be labelled. The enjoyment of food only emerged in the eleventh most important factor. This again justifies the case that consumers have very different priorities when eating out. This corresponds with priorities of beer drinkers; one group of which regarded atmosphere and pub location as having significantly greater importance than the sensory properties of the beer (Pierson *et al.* 1995). In this present study, respondents wanted most of all to be cared for by friendly and attentive staff and enjoying the food was much less

important. The findings from this factor analysis provide many ideas for the restaurateur trying to provide the best eating out experience.

The second factor analysis on the pleasure derived from a range of activities also provided an intelligible structure of factors. In this case, the eating out experience was closely linked to being with friends. This again emphasises the human social aspects of eating in the same way that the previous factor analysis showed that being cared for was important.

Maslow's hierarchy of needs (Maslow 1970) has survival in the form of adequate shelter, warmth and food as the base. Above this, human needs change to self esteem and self actualisation. The results of the first factor analysis could be explained by the hypothesis that in present times, most humans are well provided for in the basic needs and therefore take them for granted. In other words, when they visit a restaurant they are not going for survival needs but to be looked after, esteemed and cared for by other human beings. The second factor analysis explored this higher level of human needs, motivated by the search for pleasure discussed in section 1.5.1. Again, eating activities were in factors of lesser importance. The most important factor for derivation of pleasure was the contrast between those who want to be out and about (walking, rambling) and those who want to stay indoors (playing computer games and gambling) (Table 36). The second factor (travelling and holidays) also emphasised the higher level of human needs in terms of exploration as a means of self actualisation. In the present relatively affluent times, working for money only appears in the ninth factor, again suggesting that this essential means to provide the base of survival is taken for granted. Sexual activities, another basic human need, although rated as giving great pleasure was eliminated during the factor analysis. Perhaps again, this basic need is taken for granted.

2.3.5 Conclusions from Experiment 3

The survey results from this stage of the research can support the view that, based on a wide-ranging sample of respondents, the intrinsic qualities of food that a chef or a sensory analyst considers is of the greatest importance, does not coincide with the consumers' views. They considered the more extrinsic factors of 'customer care', 'drink', 'entertainment' and 'formality of the meal occasion' to be much more important than the intrinsic qualities of food in giving them pleasure when eating out. This is also supported by the place of pleasures associated with food in the range of pleasurable human activities.

These two factor analyses, in particular, provide a basis for modelling the factors affecting the pleasure of eating out and then to place that pleasure in the context of the wider range of pleasurable human activities.

3 General Discussion

This research has focused on the sous vide process which was intended to bring the high sensory quality normally associated with foods prepared by chefs in high class restaurants to foodservice applications requiring much more flexibility and efficiency of operation. This research has shown that dishes made using this process can be distinguished from conventionally prepared foods in a sensory laboratory.

Experimentation on the ability of assessors to discriminate between a conventionally and sous vide processed food in a controlled laboratory environment, found that a sous vide processed chicken dish was inferior in acceptability to the conventionally processed version (section 2.1.3).

In Experiment 2, conducted in an ecologically valid environment, it was concluded that, again, there was no evidence to suggest that consumers liked sous vide processed foods more than the conventionally processed versions (section 2.2.3). This experiment appears to have been the first to study the sensory quality of sous vide foods in its intended environment, a restaurant. All the studies summarised in Appendix B have been performed in the controlled laboratory environment with food prepared by scientists where assessors were aware that they were participating in a research experiment. In Experiment 2, a chef prepared and presented the dish so that both the assessor, unaware of any experimentation, and the food were in an ecologically valid environment.

The use of desirability values in Experiment 2 has also been the first in such a study. This concept does have some disadvantages in losing information from scales such as Relative-to-ideal where values equidistant on opposite sides of the ideal point are deemed to have the same desirability value. So, in some cases, a significant difference could be found by analysing the raw data but not when the same data had been converted to desirability values. This can be illustrated in Table 11 where a significant difference in chicken texture with mean values each side of the ideal point, disappeared when converted to desirability values shown in Table 13. If the mean values from raw data are on the same side of the ideal point as for lamb colour in Table 12, then the difference still retains significance when converted to desirability scores in Table 14. However, there is the advantage for the desirability values concept of its ability to take data from many different types of scale and bring them together on a common scale of comparability. As discussed in section 2.2.4, using a linear transformation from raw data to desirability value has been more a matter of pragmatism rather than having a particular scientific basis. The non-linear transformations in Figure 21 could be as appropriate to use as the ones in Figure 18.

It is also probably the first time that the Relative-to-ideal scale has been used to assess meals and their components as a way of checking consumer perceptions. Up until now, this scale has been used only on simple, homogeneous foods such as those mentioned in section 1.5.5 c. In the free-choice environment of a restaurant, it is not possible to vary the stimuli of meals as might be possible under laboratory conditions, so the information gained was somewhat limited. The level of anticipation of eating at the restaurant was generally high so deviations from the ideal may have been masked by the effect of expectations of a good meal. Another reason why any differences could be missed is that a meal prepared in two different ways, eaten by the same consumer in separate weeks is a very different comparison from having two samples to compare at the same time. In the latter case, a difference is induced by the experimental procedure. Meiselman (1994) agrees that consumer expectations will make multi-component meals very difficult to assess if techniques only assess the sensory aspects. O'Mahony (1995) thought that if untrained consumers found differences, the normal consumer would also. In Experiment 1, untrained consumers did find differences with a chicken dish (Table 4): in Experiment 2 although the dish was not directly comparable, the normal consumers in the restaurant did not find differences in a chicken dish (Table 11). This could be due to the myriad of extrinsic factors which have been shown to collectively overshadow the apparent dominance of the sensory properties of the meal.

In this experiment in an ecologically valid environment, despite the use of different and more appropriate methods of gathering data from consumers and analysing it with different methods, the sous vide process still appears not to exhibit the claims of sensory superiority made for it (Appendix A.1). On the other hand, it could also be argued that the commercially produced sous vide products were not distinguishable from the conventionally cooked dishes. Therefore the other advantages claimed for the sous vide process of convenience, consistent portion size and minimal wastage with the flexibility of the using a time buffer could be maximised.

Another innovation in Experiment 2 was allowing the assessor to have a second opportunity to give an hedonic score to the food under study after being prompted to consider how close the meal's attributes came to their personal ideal levels. This showed a significant change ($p<0.05$) only for sous vide processed Chicken Dijonnaise where the hedonic score fell after this reassessment (Table 15). Significant differences in attributes were also in agreement with the most important factor from the factor analysis of the complete data for chicken. It could be argued that allowing a second opportunity encourages the assessor to think more objectively and, therefore, to take into account more of the attributes which failed to match their ideal or come up to their expectations. These would then act as cues to lower their

hedonic rating of the dish. This method of asking assessors to reconsider could provide more objectivity to the use of this type of scale.

In section 1.4.6, it was thought that trying to assess some emotional aspect of the consumer's feelings in a restaurant would be difficult, but in most cases, consumers in Experiment 2 were willing to answer a questionnaire which did incorporate a question on attitude (anticipation of enjoyment).

The factor analysis for the Lamb Navarin dish also gave credence to the often quoted idea that people 'eat with their eyes'. In this case, the important factors came out in order of importance as colour, flavour, then texture of the lamb and sauce with the colour of the included vegetables coming together as the fourth factor.

Experiment 3 revealed several points relevant to the use of new systems of meal preparation by the foodservice industry. Many of these ideas have not been explored before using data gathered and analysed scientifically. The first concept was an 'Intolerance index'. As mentioned in section 2.3.3, the responses to be used on the first part of the questionnaire cannot be considered as a continuous scale, so a non-parametric test must be used to determine if any significant differences exist. This showed intolerance to meal problems for older people compared to younger people and for those in SC I compared to SC IV. This more intolerant SC I is also more likely to travel and be less neophobic. More importantly, this group eats out more frequently than other Social Classes.

This work revealed a trend for the acceptability of non-conventional methods of food production (the Technophobia index) to decrease with age and to increase with Social Class (Table 28). The variation of scores from the Food Neophobia Scale with age show an inverted U-shape, with the young and old being more neophobic than the 25 to 34 age group (Table 29). The young age group could be reflecting insecurity while the older group reflect boredom. Both these trends would have important consequences for deciding the choice of menu when targeting a particular age group or feeding older consumers. The consequences of the more frequent eater and SC I being less neophobic also have to be considered by the foodservice operator or restaurateur maintaining a menu which can satisfy these more adventurous eaters.

The factor analysis on the importance of variables encountered when eating out, emphasised the 'customer care' element of the restaurant. The idea put forward earlier that the reason for the order of factors in Table 33 could be related to Maslow's hierarchy of needs must be somewhat tentative. It does, however, make sense in the more secure society of today where most people's basic needs are well satisfied. Again, this information should serve to emphasise to the restaurateur that staff training and staff attitudes towards customers have great importance in influencing the pleasure they derive from eating out. If for some reason the meal served is

unacceptable through off-flavours, tastes, etc., the customer is most likely to react very strongly (Figure 22) so the ability of staff to maintain a friendly relationship could help to ameliorate the situation. The main point from this analysis is that just selecting and using the most obvious variable by its magnitude, does not necessarily reflect the strongest influence. A multivariate technique, such as factor analysis, can examine the underlying structure and extract a combination of related variables which give a much larger overall effect.

The present work differs from the findings of Pierson *et al.* (1995) on beer who found that consumers split into two groups, one preferring the beer and the other the social aspects of the pub. In this work, the enjoyment of food was important to all segments of the sample (Table 32).

The factor analysis examining the relationship between a range of activities in giving pleasure emphasised that 'eating out' and 'being with friends' were strongly associated. This again highlights the link between enjoying food and the company of others whether as friends or as people trying to make a restaurant customer feel welcome.

This connection of pleasure with eating out and happiness agrees with Averill and More (1993) who considered that the short-lived pleasure of eating a good meal contributed towards 'more enduring states of happiness' such as being happy with the family, for example.

4 Conclusions and recommendations

This research can conclude that the claims of sensory excellence of sous vide processed foods compared to conventionally cooked foods cannot be justified purely on the basis of scientific work performed under laboratory conditions. In an ecologically valid environment, a restaurant, employing a number of different techniques for gathering data with discriminatory tests and relative-to-ideal, attitude and hedonic scales, it is possible to state that its sensory qualities are perceived by consumers to equal those of conventionally prepared foods. Therefore the main advantages of using sous vide foods would be related to operational factors such as better portion control, lower wastage and convenience of operation where good quality meals are needed on a large scale (e.g. banqueting) or at inconvenient times (e.g. room service, shift working). Other modern systems such as cook-chill do not have the convenience of reheating in pouches and the longer chilled storage life. However, the question of whether one type of system is 'better' than any other is probably irrelevant and should be considered from the aspect of satisfying the consumer where the 'meal assembly' concept can provide the required flexibility for meal choice (Creed *et al.* 1996).

The present work also emphasises the point that just one scale such as the hedonic scale alone cannot manage to explain the complexity of the relationship between the factors affecting enjoyment of a meal.

The research has also clearly demonstrated that the intrinsic qualities of foods which form part of the consumer's enjoyment are just one component of a minor factor influencing the overall pleasure derived from eating out and that the most influential factor comprises a number of variables making up 'customer care'. This does not mean that the enjoyment of food is not important to consumers. On the contrary, this attribute had the highest value and lowest standard deviation (Table 31). Thus it was agreed by almost all respondents that the food would be enjoyed. The 'Enjoyment of food' attribute was therefore almost constant so, overall, could contribute very little to understanding the data structure and how factors influence the pleasure of eating out. Therefore it can be concluded that although, in itself, enjoyment of food is extremely important to consumers, when this is put into context, other variables are associated which form a greater influence than food on the pleasure derived from eating out.

5 Further Work

Further work could be productive in two areas. On the basis of the extensive literature survey, scientific research on the sensory aspects of foods produced by the sous vide process appear to have been restricted either by limitations on the type of meal or on the range of processing conditions used. Further research could investigate:-

- The relative contributions of the effect on consumer acceptability of:-
  i) marinating in the pouch on protein components before processing.
  ii) the low temperature/long time processing conditions.
  iii) the particular sensory qualities of sauces.
- The exploitation of the high quality image of sous vide processed foods packaged in pouches which would also appeal to particular groups of consumers requiring greater assurance of uncontaminated food:-
  i) for ethical, environmental reasons, e.g. those requiring organic products.
  ii) for ethical reasons, e.g. vegetarians, vegans, etc.
  iii) for medical reasons, e.g. allergens - free of gluten, peanuts, etc.
  iv) for religious reasons, e.g. kosher and halal products.

The second area would be developing the scales introduced in this work and devising further scales to evaluate consumer acceptability:-

- Studying the effect of age group, Social Class and other demographic data on the consumer's level of tolerance to problems with a meal - the Intolerance index - and applying this knowledge to particular target markets for eating out with, for example, innovative methods of food service..
- Studying the effect of age group, Social Class and other demographic data on the consumer's attitudes on the acceptability of food service systems - the Technophobia index- and again applying this knowledge to particular target markets for eating out where wastage must be minimised or consumption levels must be maintained, i.e. institutional foodservice.
- Studying the effect of age group, Social Class and other demographic data on the Food Neophobia score (Pliner and Hobden 1992) and again applying this knowledge to particular target markets for eating out, especially with novel cuisines.
- Devising scales which take into account consumer attitudes affecting perceived food acceptability, e.g. attitudes prevalent in particular groups which could be identified by cluster analysis of the survey data from experiment 3.

Appendix A.1

Comments on the sensory and nutritional qualities of sous vide products (adapted from Creed, 1995).

Comments	Source
'...no flavour is lost into the surrounding water or steam...'	Anon. 1987a
'...retains all of its natural flavour, along with more of its nutritional qualities...'	Anon. 1987b
'...the food retains all its flavours and fresh taste...'	Bacon 1990
'...all the nutrients, flavor, texture and aroma of the food are locked in...'	Baird 1990
'...there is no opportunity for loss of volatile flavour notes...'	Bauler 1990
'...raw or lightly cooked food product retains almost all its color, flavor and nutrients...'	Bertagnoli 1987
'...every delicate morsel of flavor is retained in the food...'	Campbell 1993
'...Dans le domaine des poissons, la concentration des parfums est très importante; le court mouillement sous vide accentue ce phénomène....' - 'In the area of fish, the concentration of aromas is very important; the short vacuum moistening accentuates this phenomenon...'	Choain & Noël 1989
'...amplifies the food's flavor; if the product is fresh, it tastes wonderful. If it's not fresh, it tastes and smells twice as bad as if you cooked it conventionally...'	Coomes 1994
'...the only possible problem can be one of too much flavor. You've got to know how to make certain things lose their flavor...'	De Liagre 1985
'...enhances flavor and aroma...'	Ivany 1988
'...the integrity and taste of the food is generally considered superb...'	Kalinowski 1988
'...the best lamb they'd ever tasted...'	Levine and Rossant 1987
'...tasted like real food...'	Levy 1986
'...the process intensifies flavour...'	Manser 1988
'...food that tastes like it was freshly made...'	Petit 1990
'...Mais leur grande surprise a été de découvrir le vrai goût naturel de chaque aliment,...' - 'But their great surprise has been to discover the true natural taste of each food,...'	Pralus 1985
'...the flavours can't escape...more taste and smell...the texture of the food is constant...'	Pring 1986
'...seals in flavour, juices and nutrients...'	Raffael 1984
'...does not harm the color, texture or flavour of food...'	Scarpa 1988
'...its flavour is highly praised in haute cuisine circles...'	Sellers 1990
'...retain flavouring...reduce the loss of vitamins and nutrients in the cooking process...'	Sessions 1987
'...the quality of the final products are often far superior to foods prepared in the traditional manner...'	Sornay 1990

Appendix A.2

Advantages, disadvantages and reasons for success or failure of using sous vide processed foods (summarised from Creed and Reeve, 1998).

A. Advantages

(a) Cost benefits	• Adding value to basic raw materials such as meat and fish by producing chilled prepared meals. • Cutting food costs by reducing materials for enhancing flavours. • Tighter portion control. • Lower weight loss through retention of moisture in packaging. • Lower wastage due to quicker response to consumer demand. • Extension of shelf-life leading to lower wastage during storage. • Economies of scale for variable food costs using a centralised production unit to supply several outlets. • Lower capital costs by centralising location and use of equipment for production. • Option to eliminate central production unit by buying in meals from a manufacturer.
(b) Labour cost benefits	• Using less skilled or fewer skilled staff. • Easier staff recruitment. • More rapid service of food to the consumer. • Easier room service and banqueting preparation. • Higher productivity in terms of food produced per man hour. • Easy incorporation into a meal assembly system.
(c) Quality benefits for food and service	• Reducing problems due to oxygen by vacuum packing. • Reducing risk of contamination through use of vacuum packing. • Claimed superior sensory qualities. • Claimed superior nutritional qualities relevant to hospital patients. • Enabling production of pre-cooked foods otherwise needing long processing times (e.g. dried vegetables). • Higher quality of service due to less time on repetitive food preparation. • Higher perceived quality of food due to more time for presentation. • Better career development for chefs.
(d) Marketing advantages	• Strong image of *haute cuisine* restaurant dishes with endorsement by respected chefs. • Flexibility offered by a wide menu range. • Innovative concept for the use of technology. • Wide range of sizes from individual to multi-portion for foodservice.

Appendix A.2 continued.

B. Disadvantages

(a) Material costs	• Cost associated with equipment and systems required for more stringent quality management systems to ensure food safety through monitoring raw materials, heat treatment storage, distribution etc. • Higher capital costs of equipment for preparation, vacuum packing, pasteurising, chilling and storage. • Higher costs for packaging. • Higher costs for using devices for detecting temperature abuse.
(b) Labour costs	• Costs of training for staff at all levels as part of the more stringent quality management systems. • Developing suitable recipes. • Overcoming staff resistance relating to deskilling. • Costs of staff to liaise with suppliers and customers as part of the quality management system.
(c) Quality costs	• Increased risk of food poisoning if sous vide packs are subjected to temperature abuse.
(d) Marketing costs	• Ensuring reliable delivery of chilled foods over a wide geographical area. • Overcoming fears of the consumer on food safety through education. • Overcoming confusion between pasteurised sous vide products and sterilised 'boil-in-the-bag' products. • Setting price of sous vide foods to ensure return on capital invested in equipment, training, etc.

C. Reasons contributing to success or failure in the commercial use of sous vide processed foods

Success	• A realistic attitude towards likely sales volume. • Supplying foods meeting customer requirements whether sous vide processed or not. • Emphasising advantages of portion control, reduction of labour costs and increased convenience as opposed to the 'haute cuisine' image. • Selling the product at a realistic price.
Failure	• Low market acceptance due to reservations of users and retailers on food safety. • An emphasis on marketing the technology and not its benefits. • Incorrect price/quality ratio giving poor profit margins. • Lack of profitability due to high start-up investment costs linked to expected short pay-back periods. • Professional resistance to pre-cooked foods. • Costs and reliability of distribution over a wide area. • Consumer concerns on food safety and lack of product knowledge.

Appendix A.3 Applications of the sous vide method to industrial and foodservice problems (summarised from Creed and Reeve, 1998).

Area of Application	Application	Reference
Industrial		
Meat processing	Production of cooked joints/sliced cooked meats	Van der Leest 1985
	Production of pasteurised sausages (Germany)	Wiesel 1987
	Adding value to meat by selling it as prepared meals	Pröller 1990
Fruit and vegetable processing	Improvement in quality over frozen or sterilised fruit and vegetables (France)	Varoquaux and Nguyen The 1994
	Process of vacuum, steam injection pasteurisation, vacuum cooling to improve sensory quality (France)	Varoquaux *et al.* 1995
Seafood processing	Consumer packs of salmon with pasta for retail sale	Urch 1991
	Vacuum packing salmon slices for end user cooking	Varney-Burch 1991
	Extension of the shelf-life of crab meat	Hackney *et al.* 1991
	Extension of chilled convenience fish products	Ghazala 1994
	Sous vide processing of salmon (Norway)	Bergslien 1996
Retail	Retail sale (France and Belgium)	Martens 1995
	Ban on some sous vide products for retail sale (U.S.A.)	Schwarz 1988
	'Boutiques' selling sous vide products (U.S.A.)	Riell 1988
	Market testing of GourmetFresh products (U.S.A.)	Rice 1991
	Poor delivery of Culinary Brands' products (U.S.A.)	Millstein 1990
	Supermarket sales of sous vide dishes to rise (U.S.A.)	Jones 1996
	Research on retail sous vide products (Belgium and France)	Martens 1996
	Consumer survey (Belgium)	Anon. 1993
Hotels and restaurants		
Restaurant	Problems of no 'real chef' in the kitchen (U.K.)	Bristol 1989, Gledhill 1991
	Le Petit Cuisinier supplying Flunch chain (France)	Goussault 1992
	Grace Culinary supplying American Café (U.S.A.)	Swientek 1989
	Petroleum Club in New Orleans cut food costs (U.S.A.)	Bertagnoli 1987
	Central production unit cuts investment costs (U.S.A.)	Scarpa 1988
	European supplier for a restaurant chain (U.K.)	Glyn 1993
Room service and banquets	Less wastage at the Gatwick Hilton (U.K.)	Stacey 1985
	Better room service at the Brussels Hilton	Bertagnoli 1987
	To overcome skills shortage at Marriott Hotels (U.S.A.)	Schecter 1990
	Easier banquet preparation at Scharzenberg Palace, Vienna (Austria)	Raffael 1984
	More banqueting business at the Brussels Hilton	Coomes 1994
	Easier organisation of banquet and outside events (U.S.A.)	Scarpa 1988, Bertagnoli 1987
	Financial and labour benefits for room service, banqueting and restaurants in Holiday Inns (U.K.)	Johns *et al. 1992*

Appendix A.3 Applications of the sous vide method (continued)

Transport		
In-flight foodservice	High quality and flexibility of a wide menu range	Gostelow 1989
	Using Culinary Brands sous vide products (U.S.A.)	Anon. 1989
	Supplying Iberia and Swissair at Malaga Airport, (Spain)	Gehrig 1990
	Use of the sous vide method by various airlines	Coomes 1994 , Anon. 1988b, Raffael 1985a
Railway foodservice	Use by SNCF on high speed TGV trains (France)	Raffael 1984, De Liagre 1985, Chauvel 1992
	Use on VIA Rail (Canada)	Kalinowski 1988, Bristol 1989
	Use on Irish Rail (Ireland)	Bacon 1989
	Use on Swiss Railways (Switzerland)	Gostelow 1990
Marine foodservice	On yacht crossing the Atlantic	MacNeil 1987
	On France/Corsica ferries	Moisy 1990
	On English Channel ferries	Thomas Morel 1994
Institutional		
Military foodservice	Improvement of usual military rations	Baird 1990
	Air force (France)	Schamberger 1991
Industrial foodservice	Peugeot-Talbot car factory at Poissy (France)	Eustache 1988, Defais and Elman 1989, Anon. 1991
	Central kitchen of the EC (Belgium)	Mouligneau 1996
Hospital foodservice	For special diet dishes and catering for banquets	Sessions 1987
	Easier supply of low calorie, low fat or low salt meals	Choain and Noël 1989
	Health clinic at Deauville (France)	Raffael 1985b
	Hospitals at Den Bosch and Boxtel (Netherlands)	Verbraken 1993
School and college foodservice	Centralised production for school meals at Nice (France)	Anon. 1988a, Ward 1988
	At Lyon to supply 200 school dining rooms (France)	Lepage 1990
	Centralised production unit at Catholic University of Leuven (Belgium)	Martens 1993, Wolthuis 1993
	State University at Ghent (Belgium)	Van Oyen 1993

Appendix A.4 Summary of world activity in the production, application, education and research on sous vide processed foods from 1984 to 1998, (summarised from Creed (1996, 1998), Martens (1995)).

	Production		Application				Educat-ion	Research
	Manu-facture	**In-house**	**Hotels/ restaur-ants**	**Institu-tional**	**Retail**	**Trans-port**		
Africa								
Senegal							X	
South Africa		X	X					
America								
Argentina	X						X	
Canada	X	X	X		X	X		X
Mexico							X	
U.S.A.	X	X	X		X		X	X
Asia								
Hong Kong		X	X					
Japan		X	X				X	X
Singapore		X	X					
Taiwan								X
Australasia								
Australia	X	X	X				X	X
New Zealand	X	X	X					
Europe								
Austria			X					
Belgium	X	X	X	X	X	X	X	X
Czech Rep.							X	X
Denmark		X	X		X	X	X	X
Finland								X
France	X	X	X	X	X	X	X	X
Germany	X							X
Greece								X
Iceland							X	
Ireland	X	X	X			X	X	X
Italy	X							X
Luxembourg							X	
Netherlands	X	X	X	X	X		X	X
Norway	X	X	X		X		X	X
Poland								X
Portugal								X
Spain	X	X	X	X		X		X
Sweden	X							X
Switzerland	X		X			X	X	X
Turkey								X
U.K.	X	X	X		X	X	X	X

Appendix B Summary of research on sensory aspects of sous vide foods.

In this appendix, the reference numbers refer to points in section 1.4.6 and the following abbreviations are used:-

0	No difference or sous vide is the same as the other treatment.
+	Sous vide is superior to the other treatment.
-	Sous vide is inferior to the other treatment.
CIB	cook-in-bag.
Dec	Decreasing as time or temperature increases.
Inc	Increasing as time or temperature increases.
SV	sous vide.
TBA	Thiobarbituric acid, a test for lipid oxidation and hence rancidity.
TBARS	Thiobarbituric acid reactive substances, a test for lipid oxidation and hence warmed-over flavour in foods.
WB	Warner Bratzler method for shear force measurement.
Y	Yes, there is a difference.

Appendix B.1 Meat-based sous vide products.

Food type	Comparison	Tests used	Attributes	Results	Reference	No
Beef roasts	CIB/ conventional	Descriptive analysis	tenderness	+	Buck *et al.* 1979	1
			juiciness	0		
			acceptability	+		
		WB	shear force	+		
Beef muscles	CIB/ conventional	Descriptive analysis	colour uniformity	+	Dinardo *et al.* 1984	2
			tenderness	+		
			juiciness	+		
			flavour	+		
		WB	shear force	+		
Pork roasts	CIB Chilled /frozen	Descriptive analysis	pork flavour	0	Jones *et al.* 1987	3
			off-flavour	0		
		WB	shear force	0		
Beef chuck roasts	CIB/ conventional	Descriptive analysis	tenderness	0	Stites *et al.* 1989	4
			juiciness	0		
			beef flavour	+		
			off-flavour	0		
		WB	shear force	0		
Roast beef	SV/ conventional	Qualitative descriptive analysis	colour uniformity	+	Choain & Noël 1989	5
			aroma	-		
			taste	+		
			texture	+		

Appendix B.1 Meat-based sous vide products (continued)

Food type	Comparison	Tests used	Attributes	Results	Reference	No
Blanquette of veal	SV/ conventional	Qualitative descriptive analysis	colour uniformity aroma taste texture	+ - + +	Choain & Noël 1989	6
Beef loin roasts	CIB/ conventional	Instron WB	shear force	0	Cooksey *et al.* 1990	7
Minced lamb in pastry	SV Chilled/ frozen	Descriptive analysis	appearance flavour aftertaste texture	0 0 0 0	Schafheitle & Pierson 1992	8
Pork meat	SV/ conventional	Qualitative descriptive analysis	colour flavour tenderness	0 0 0	Lefort *et al.* 1993	9
Pork chops and roasts	CIB Storage time	Descriptive analysis	juiciness flavour off flavour tenderness	0 0 0 0	Cannon *et al.* 1995	10
Beef slices Beef joints	SV Storage time	TBARS TBARS Descriptive analysis	warmed-over flavour off-odour off-flavour	Inc 0 Inc Inc	Hansen *et al.* 1995, Bertelsen & Juncher 1996	11
Nikujaga (potato/ beef/ soy sauce)	SV/ conventional	Paired comparison	appearance colour flavour taste softness preference	+ 0 + + + +	Goto *et al.* 1995	12
Pork fillet	SV/ conventional	Instron	hardness cohesiveness springiness gumminess chewiness	+ + + + +	Goto *et al.* 1995	13
Beef bolognaise	SV profiling	QDA	20 descriptors		Armstrong 1996	14
Beef	SV Marinating Storage time	Descriptive analysis	tenderness tenderness taste odour	+ 0 0 0	Thorsell 1996	15

Appendix B.2 Poultry-based sous vide products.

Food type	Comparison	Tests used	Attributes	Results	Reference	No
Chicken breast	SV cooking temperature/ time	Consumer	acceptability	90° C for 20 mins.	Nazaire 1987	16
Chicken à la King	SV fresh/ stored	Paired comparison	difference	N	Light *et al.* 1988	17
		Descriptive analysis	appearance	0		
			flavour	Inc		
Turkey breast rolls	CIB storage time	WB	shear force	Dec	Smith & Alvarez 1988	18
		Hunter	colour	0		
Chicken ballotine	SV fresh/ stored	Triangle	difference	Y	Schafheitle & Light 1989a, b	19
		Descriptive analysis	appearance	0		
			odour	0		
			juiciness	0		
			flavour	0		
			texture	0		
			acceptability	0		
Minced chicken breast	CIB salt concentrat-ion	WB	shear force	Inc	Rosinski *et al.* 1989	20
Chicken ballotine	SV/ conventional	Triangle	difference	Y	Church 1990	21
		QDA	aroma	+		
			juiciness	+		
			moistness	+		
			flavour	+		
Chicken velouté	SV/ cook-chill/ cook-freeze / storage time	Descriptive analysis	aroma	0	Smith & Fullum-Bouchard 1990	22
			appearance	0		
			flavour	0		
			tenderness	0		
Chicken/ prawn/ pastry	SV chilled/ frozen	Descriptive analysis	appearance	0	Schafheitle & Pierson 1992	23
			flavour	0		
			texture	0		
Chicken/ bacon/ pepper/ pastry			aftertaste	0		
Chicken breast	SV storage time irradiation	Descriptive analysis	aroma	0	Shamsuzzaman *et al.* 1992	24
			flavour	0		
Chicken in red wine sauce	SV/ conventional/ storage time	Duo-Trio	difference	Y	Creed *et al.* 1993	25
		Descriptive analysis	acceptability	-		
Chicken breast	SV/ conventional	Instron	hardness	+	Goto *et al.* 1995	26
			cohesiveness	+		
			springiness	+		
			gumminess	+		
			chewiness	+		
Chicken breast	SV storage time / irradiation	Descriptive analysis	aroma	0	Shamsuzzaman *et al.* 1995	27
			flavour	0		
			texture	0		

Appendix B.2 Poultry-based sous vide products (continued)

Food type	Comparison	Tests used	Attributes	Results	Reference	No
Chicken boiled in cream	SV/ conventional	Paired comparison	appearance	0	Goto *et al.* 1995	28
			colour	0		
			flavour	0		
			taste	0		
			softness	0		
			preference	0		
Brined chicken breasts	SV cooking temperature	Descriptive analysis	meaty	0	Turner and Larick 1996	29
			warmed over flavour	0		
			saltiness	0		
			soapy/ bitter	Inc		
			tenderness	Inc		
			juiciness	Dec		
		Minolta	colour	0		
		Instron WB	shear force	0		
	SV storage time	Descriptive analysis	meaty	Dec		
			warmed over flavour	Inc		
			saltiness	0		
			soapy/ bitter	0		
			tenderness	0		
			juiciness	0		
		Minolta	colour	0		
		Instron WB	shear force	0		
Chicken breast	SV/ cook-chill/ stored	Descriptive analysis	appearance	+	Church 1996	30
			flavour	+		
			off-flavour	+		
			tenderness	0		
			juiciness	+		
			hedonic appeal	+		
Chicken	SV cooking time/ temperature	Descriptive analysis with fuzzy logic	colour juiciness flavour texture acceptability		Xie *et al.* 1996	31
Chicken Tikka Masala	SV profiling	QDA	16 attributes		Armstrong *et al.* 1997	32
Turkey breast	SV/ Conventional/ storage time	Carl Zeiss Instron Descriptive analysis	colour	0	Werlein and Wilkinson 1998	33
			shear force	+		
			odour	+		
			flavour	+		
			juiciness	+		
			tenderness	+		
Chicken à la King	SV/ cook-chill/ cook-freeze / conventional / storage time	Descriptive analysis	appearance	0	Edwards *et al.* 1998	34
			smell	0		
			flavour	+		
			texture	0		
			acceptability	+		

Appendix B.3 Fish-based sous vide products.

Food type	Comparison	Tests used	Attributes	Results	Reference	No
Trout/ cucumber	SV/ conventional	Qualitative descriptive analysis	appearance aroma flavour texture	0 + + 0	Choain & Noël 1989	35
Fish stock	SV/ conventional	Qualitative	appearance aroma flavour texture	+ + + 0	Choain & Noël 1989	36
Salmon Whiting	SV cooking temperature	Descriptive analysis	toughness	Inc	Picoche 1991	37
Haddock in pastry	SV chilled/ frozen	Descriptive analysis	appearance flavour texture aftertaste	0 0 0 0	Schafheitle & Pierson 1992	38
Salmon	SV storage time	QDA Instron WB Hunter TBA	colour fishy odour flakiness crumbliness acceptability shear force colour rancidity	0 Inc 0 0 0 0 0 Inc	Gittleson *et al.* 1992	39
Sea bass Gilthead sea bream	SV cooking temperature Storage time	Descriptive analysis	colour odour	0 0	Sarli *et al.* 1993	40
Saba-nituke (mackerel/ soy sauce)	SV/ conventional	Paired comparison	appearance colour flavour taste softness preference	0 0 0 0 0 0	Goto *et al.* 1995	41
Salmon	SV cooking temperature/ time Storage time	Descriptive analysis	appearance odour flavour rancidity tenderness	Dec Inc Dec Inc Dec	Bergslien 1996	42
Salmon	SV cooking time/ temperature	Descriptive analysis with fuzzy logic	colour juiciness flavour texture acceptability		Xie *et al.* 1996	43

Appendix B.4 Fruit-based sous vide products.

Food type	Comparison	Tests used	Attributes	Results	Reference	No
Poached pears	SV/ conventional	Qualitative descriptive analysis	appearance	0	Choain & Noël 1989	44
			aroma	+		
			flavour	+		
			texture	+		
Apple / Pears	SV cooking temperature	Descriptive analysis	tenderness	Inc	Picoche 1991	45
Kiwi fruit sauce	SV/ conventional	Hunter	colour	0	Goto *et al.* 1995	46
Fig compote	SV/ conventional	Paired comparison	appearance	+		
			colour	+		
			flavour	+		
			taste	+		
			softness	+		
			preference	+		

Appendix B.5 Vegetable-based sous vide products.

Food type	Comparison	Tests used	Attributes	Results	Reference	No
Potatoes	CIB/canned	Triangle	difference	+	Poulsen 1978	47
Courgettes provençale	SV fresh/ stored	Paired comparison	difference	Y	Light *et al.* 1988	48
	Storage time	Descriptive analysis	odour	Inc		
			crispness	Dec		
Dauphinoi-se potatoes	SV/ conventional	Triangle	difference	Y	Church 1990	49
Vegetable rice		Triangle	difference	Y		
Onions Carrot	SV cooking temperature	Descriptive analysis	tenderness	Inc	Picoche 1991	50
Broccoli	SV/ boil/ steam	Descriptive analysis	green colour	0	Petersen 1993	51
			flavour	+		
			bitterness	+		
			softness	+		
			acceptability	-		
Carrots	SV/ freeze	Instron	extrusion force	0	Varoquaux and Nguyen-The 1994	52
		Hunter	colour	0		
Courgettes		Instron	extrusion force	-		
		Hunter	colour	0		
Lentils	SV cooking temperature	Instron	firmness	Dec	Varoquaux *et al.* 1995	53
		Observation	wholeness	Dec		
Takikomigoh an (mixed rice) Rolled cabbage	SV/ conventional	Paired comparison	appearance	0	Goto *et al.* 1995	54
			colour	0		
			flavour	-		
			taste	0		
			softness	+		
			preference	0		
Mitsuba	SV/ conventional		colour	0	Yoshimura *et al.* 1995	55
			aroma	+		
			flavour	+		
			acceptability	0		
Carrot	SV cooking time/ temperature	Descriptive analysis with fuzzy logic	colour		Xie *et al.* 1996	56
			juiciness			
			flavour			
			texture			
			acceptability			
Potatoes in cream	SV/ cook-chill/ stored	Descriptive analysis	appearance	Dec	Church 1996	57
			moistness	Dec		
			flavour	+		
			off-flavour	0		
			firmness	0		
			hedonic appeal	+		
Green beans	SV storage time	Minolta	colour	Dec	Knøchel *et al.* 1997	58
		Instron	shear force	0		
		Descriptive analysis	bean odour	Dec		
			grass odour	Inc		
			fresh flavour	Dec		
			sweet flavour	0		
			sourness	Inc		
			hardness	0		
			crunchiness	Dec		
			juiciness	Dec		

Appendix C Models of food acceptance

i) Sequential approach - showing the factors sequentially through the process of the consumer accepting food.

Pilgrim (1957)

.....has taken a directly sequential approach, emphasising the practicalities of measurement by dividing the components of food acceptance into three groups - attitudes, physiology and sensation (Figure C-1). In this model, the two planes represent the combinations of physiological and attitudinal factors as affected by duration and time respectively with factors which can vary from being wholly food (+) to wholly non-food (-) dependent.

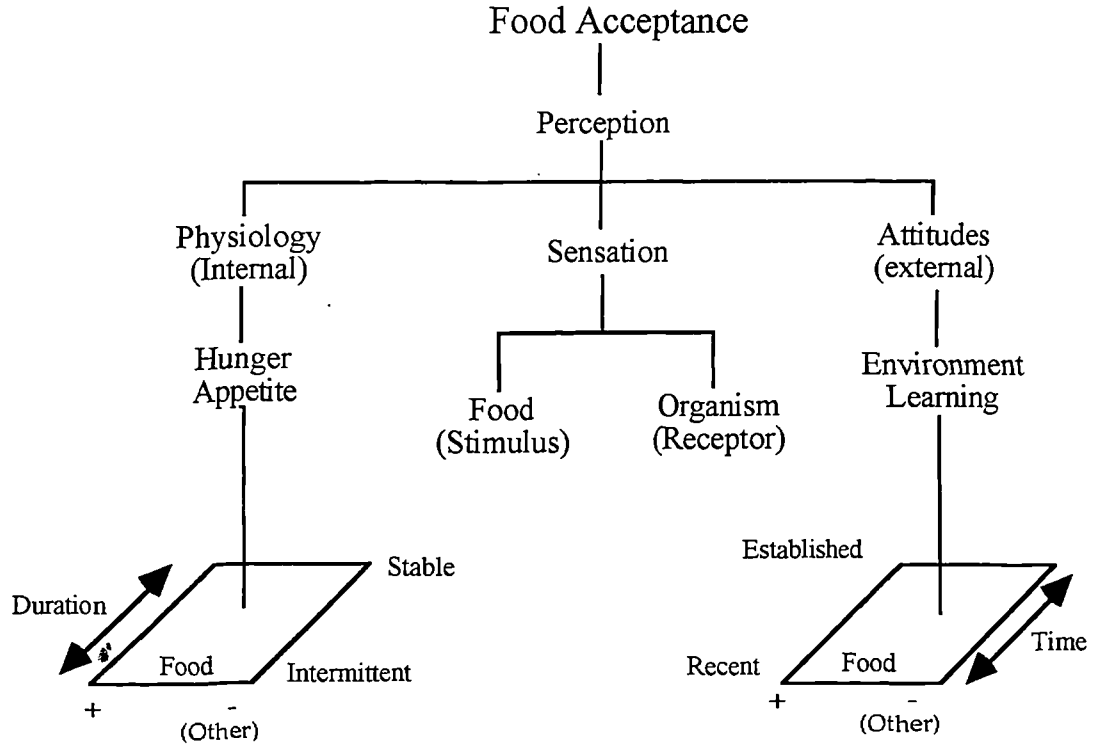


Figure C-1 Relationship between methods of measurement and components of food acceptance, adapted from Pilgrim (1957).

Land (1983)

.....took a similar sequential approach with his model (Figure C-2), adding food processing variables and more details of external marketing influenced factors affecting the integration of information, noting that this model could be one of several variants.

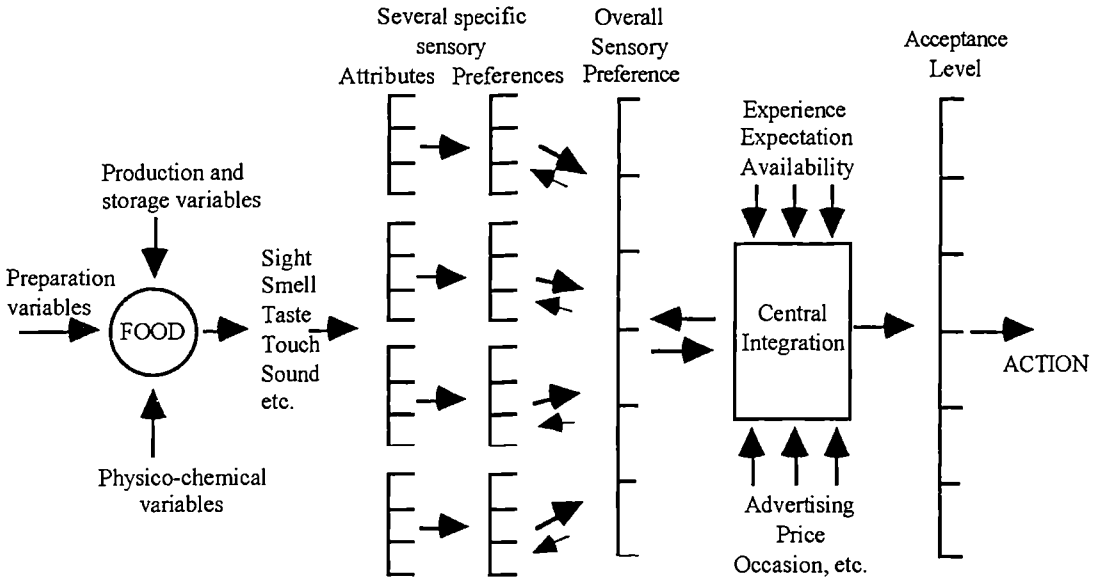


Figure C-2 Schematic model of sensory and cognitive inputs resulting in food acceptance action, adapted from Land (1983).

Shepherd (1985)

..... from a more focused point of view, produced a model of the factors affecting food preference or choice as shown in Figure C-3.

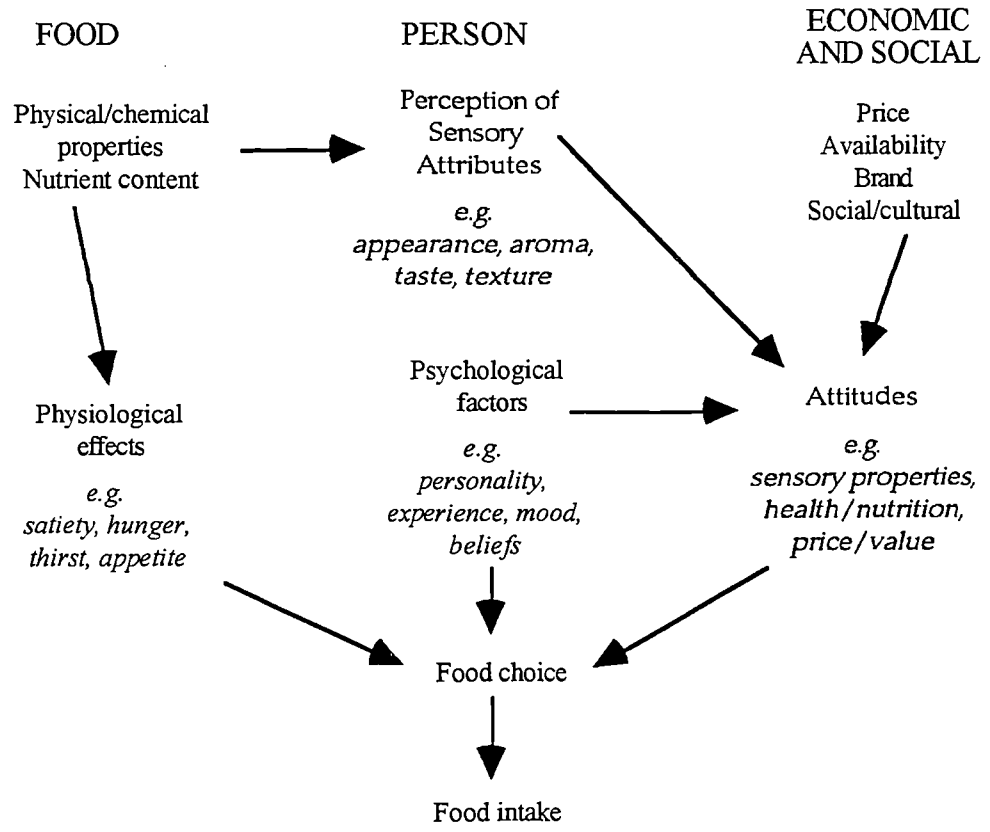


Figure C-3 Factors affecting food choice (Shepherd 1985).

Piggott (1994)

.....used a simplified flow diagram of food from materials to acceptance (Figure C-4), focusing on flavour.

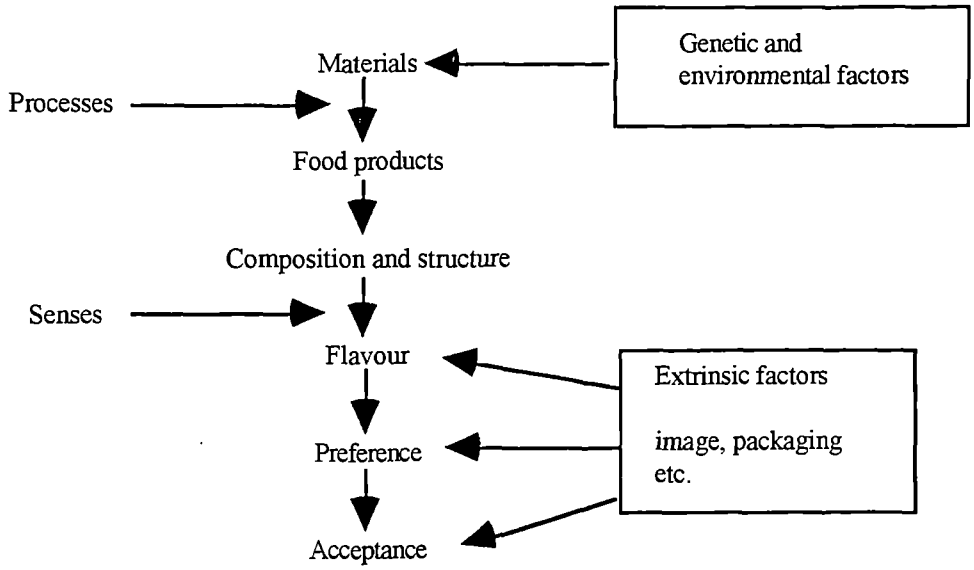


Figure C-4 Influences on food flavour, acceptability and preference (Piggott 1994).

Cardello (1994)

.....believed that the approach of the cognitive psychologist, assessors' direct reports, was the most valid. He proposed a model of food-related behaviours (Figure C-5), an example of a sequential approach with emphasis on the behavioural variables and how they provide feedback.

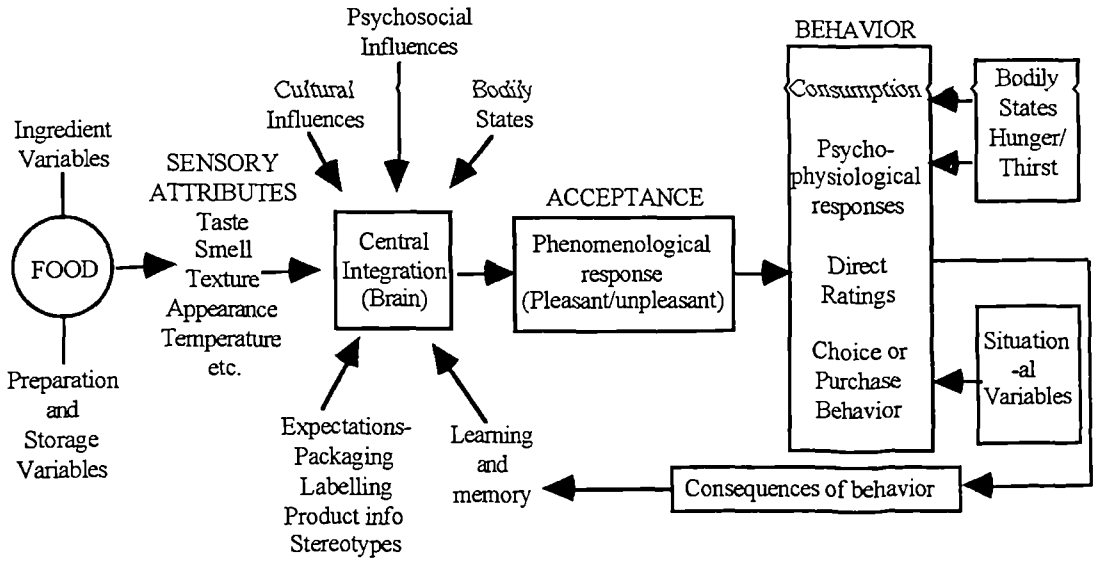


Figure C-5 Schematic model of food behaviours (Cardello 1994).

Cardello (1996)

..... organised the factors influencing food acceptance from the point of view of information processing (Figure C-6), rather than the neural mechanism approach of Harper (Figure C-7). In this case, food acceptance is 'a phenomenological experience, best categorised as a feeling, emotion or mood with a defining pleasant or unpleasant character.' This model also incorporates psychologically influenced factors such as learning, memory, context and expectations.

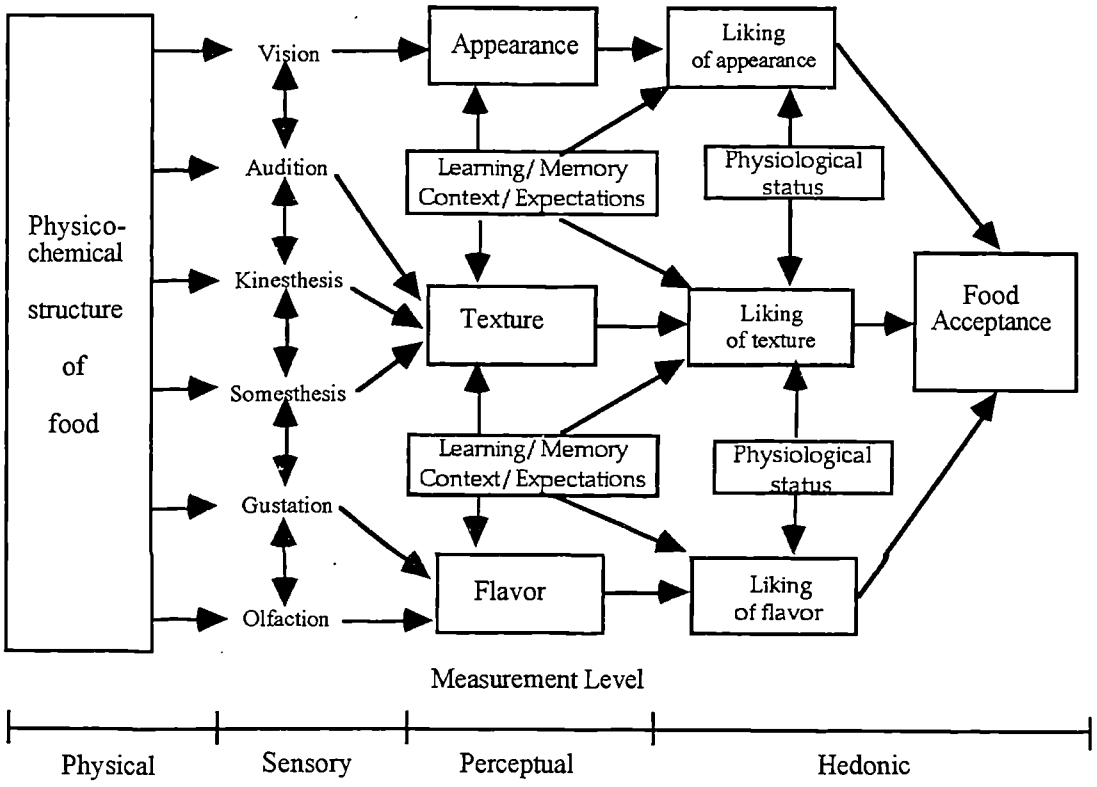


Figure C-6 Schematic diagram showing the basic sensory, perceptual and hedonic stages involved in the processing of information about the physicochemical structure of food and resulting in food acceptance behaviour (Cardello 1996).

All six models show a sequence of events moving from the stimuli provided by the food itself, the consequent sensations produced and to a varying extent take into account how these sensations are influenced by internal and external factors to affect the degree of acceptance of that food by the consumer.

ii) Interactive approach.

Harper (1981)

.....proposed another scheme to clarify the relationship with physical and sensory variables and also presented by Frijters (1988) (Figure C-7). This model places a strong emphasis on the internal mechanisms of the brain (dotted lines in Figure C-7) and is intended to map out the factors which sensory analysts and food scientists can measure so does not explicitly incorporate the effects of social, psychological and cultural factors influencing the consumer.

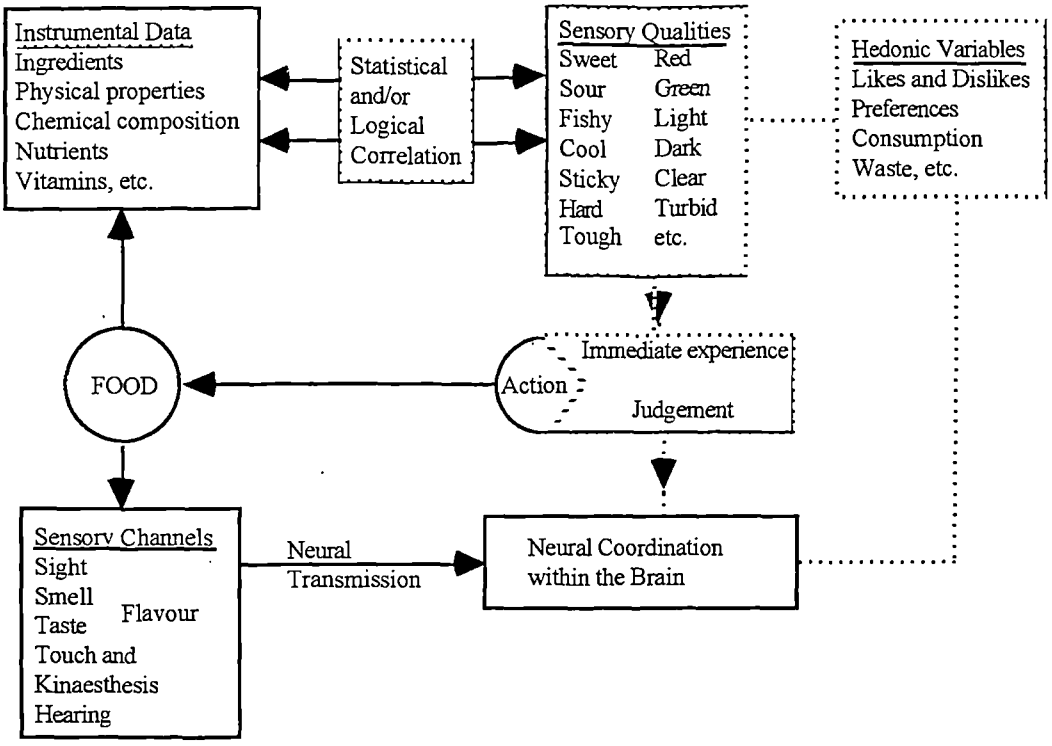


Figure C-7 Harper's scheme relating physical, sensory and affective variables associated with food (from Frijters 1988).

Khan (1981)

.....provided an example of a wide-ranging interaction model without detailing the mechanisms involved, where choice is a function of food consumption, preference, ideology and social-cultural parameters (Figure C-8). He considered that food acceptance leads to food preferences and then to food selection with important consequences for planning consumption and menus and nutritional evaluation in institutional foodservice and commercial catering.

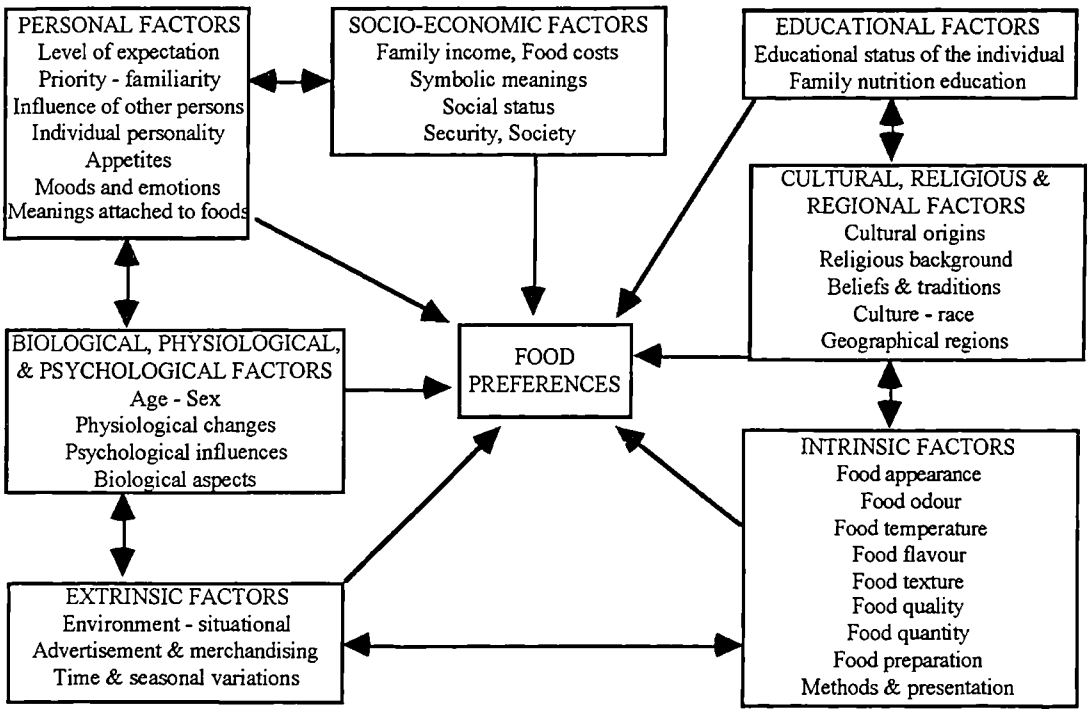


Figure C-8 Factors influencing food preferences, adapted from Khan (1981).

iii) Listing factors

Randall and Sanjur (1981)

.....using the simpler approach of just listing factors, studied food preferences which they equated to liking according to Pilgrim (1957), and divided the factors into three groups (Figure C-9).

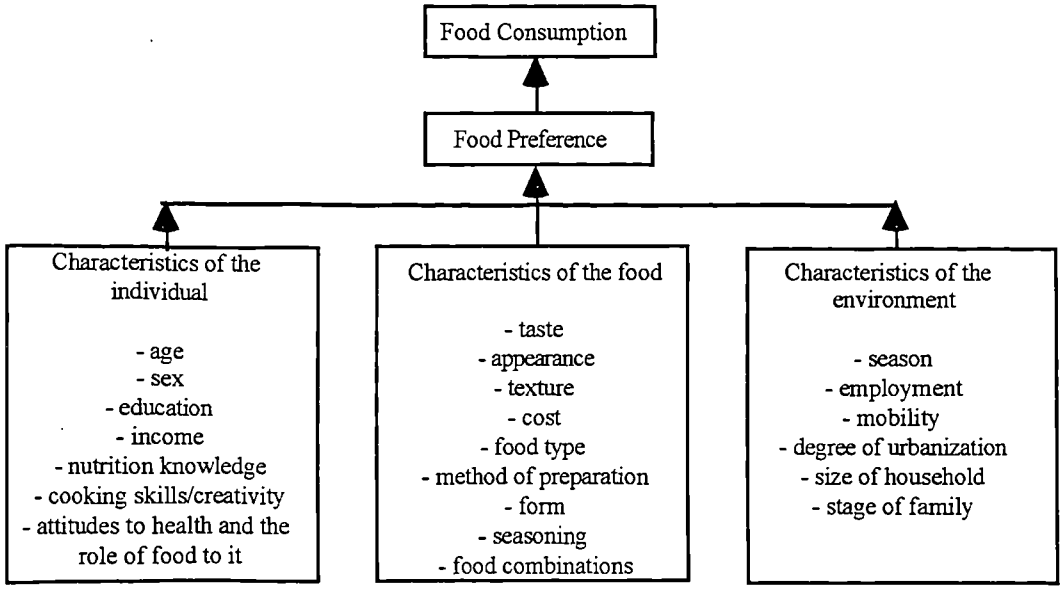


Figure C-9 A theoretical model for the study of food preferences, adapted from Randall and Sanjur (1981).

Land (1988)

..... also divided some of the psychological and physiological factors affecting food acceptance into two groups, those connected with the individual consumer and those connected with the food product itself (Figure C-10). Missing from Land's list is the third group - the situational factors which are open to manipulation by the foodservice operator in many ways, some of which have been added in Figure C-10. Meiselman (1996a) refers to these three groups as 'the food, the situation and the individual'. Meiselman (1994) noted the move in research from pure sensory evaluation of food to evaluation of food taking into account 'social and cultural factors, individual psychological factors, situational or contextual factors, economic factors and physiological factors', considering that the context of the eating situation was essential for predicting outcomes such as consumption, etc. (Meiselman 1996a). Schutz (1994a) also thought that some characteristics, although of low intensity, may make a larger contribution to how much a product is liked compared to some of the obvious attributes.

Human factors	Product factors	Situational Factors *
Experience, exposure, taboos	Breed, cultivar	Physical environment
Expectations/cues */ appropriateness *	Environment	Social environment
Sensitivity	Maturity	Advertising and marketing
Physiological state	Processing, packaging	Service level
Personality, security	Storage	Meal combination
Occasion/values/ attitudes */beliefs *	Preparation, cooking, adjuncts	
Finance	Contamination	
Mood	Availability	

Figure C-10 Some factors influencing food acceptability adapted from Land (1988) with additions *.

iv) Other models

Maslow's Hierarchy of Human Needs (Maslow 1970) is also put forward by Fieldhouse (1986) as a useful way of understanding human food choice and concludes that theories which propose that food choice is made on rational decisions based on nutritional grounds will be futile; cultural needs must always be considered. Fieldhouse (1986) also quotes several models for food choice, answering the question of why humans choose to eat particular foods. Sanjur (1982) summarised other food choice models based on motivation as :-

- Environmental models - based mainly on childhood knowledge and motivations.

- Ecological models - based on the effect of objective physical and technological availability on subjective psycho-social factors.
- Motivational models - choice is dictated by those who control the channels through which food is made available and the values of taste, health, social status and cost influencing them.

Although these models between them incorporate factors which can affect food acceptance, they do not appear to have been tested by actually measuring the effect of these factors in normal eating situations.

Appendix D.1-a.

Recipe for red wine sauce used in Experiment 1.

The sauce was prepared by heating 785 g chopped carrots, 275 g chopped celery and 470 g chopped onions in a large pan and adding 1.5 litres of French red table wine. This was simmered until the volume was reduced by approximately one half. At this stage 25 g chicken bouillon and 568 g of Maggi Chicken Provençale seasoning mix (Nestlé Co. Ltd, Croydon, Surrey, U.K.) consisting of tomato powder, wheatflour, modified starch, salt, garlic, hydrogenated vegetable oil, monosodium glutamate, sugar, herbs, onion, pepper, were mixed in. Five litres of water were added gradually and the sauce simmered for further reduction of volume. After the vegetables were sieved out, this produced 4.5 litres of sauce which was then cooled to 3°C.

Appendix D.1-b. Questionnaires used in Experiment 1.

Bournemouth University - Food Research Group

You are presented with a sample of chicken in red wine sauce labelled CONTROL.

Please look at and taste a portion of this chicken to familiarise yourself with its appearance, flavour and texture.

You are now presented with two CODED samples of chicken in red wine sauce.

Please taste each one separately and compare the appearance, flavour and texture with that of the CONTROL.

When you have done this, please answer the following questions.

1. Did you find any differences when comparing either CODED sample with the CONTROL ? .....

2. If differences were found, which CODED sample was least like the CONTROL ? .....

3. Using your own words, please describe any differences you found between the CONTROL and the CODED sample which was least like the CONTROL.

.....

.....

.....

4. Please tell us by marking the line below with the sample codes, how acceptable you found the two CODED samples.

Totally acceptable	Moderately acceptable	Just acceptable	Just unacceptable	Moderately unacceptable	Totally unacceptable

Thank you for your help.

Appendix D.2-a

Commercial recipes and instructions used in Experiment 2 for sous vide meals

a) For 10 kg Lamb Navarin sauce	(kg)
Onions silverskin	2.680
Tomato puree	1.320
Water	6.680
Flour - plain	0.340
Col-flo 67 modified starch	0.200
Major lamb stock	0.170
Gravy browning	0.060
Salt - cooking	0.150
Pepper - ground black	0.012
Garlic powder	0.012
Rosemary frozen	0.040
Total	11.664
Yield	10.000

Mix all ingredients except onions and herbs. Heat slowly to boiling to thicken. Add herbs and onions. Check yield and consistency.

Product make up (for 1 x 280 g unit)
120 g browned leg of lamb 3/4 to 1 inch dice, 120 g sauce, 20 g raw button mushrooms, 20 g (2) turned carrots

Commercial processing
4 to 6 hours at 85°C or until lamb tender.

b) For 10 kg Chicken Dijonnaise sauce	(kg)
Vegetable oil	0.085
Onions diced 8 mm	2.000
Mustard -Dijon	2.000
Col-flo 67 modified starch	0.181
Sugar granulated	0.330
Vermouth	0.800
Salt - cooking	0.140
Pepper - cracked black	0.035
Cream - whipping	6.000
Total	11.571
Yield	10.000

Sweat down onions in oil until soft. Add all other ingredients except vermouth and Col-flo. Mix vermouth and Col-flo. Add slurry to sauce just off the boil. Check yield and consistency.

Product make up (for 1 x 250 g unit)
1 x chicken supreme 170 to 200 g skin off, sprig bone on and 90 g sauce.

Commercial process 40 minutes at 90°C

Recipes and procedures used in Experiment 2 for conventional meals

The ingredients used were the same as the sous vide versions of the meals detailed above.

For conventional Lamb Navarin preparation,

Heat dripping in a frying pan, season the meat and fry brown on both sides in the hot fat. Remove the meat and place in a braising pan.

Fry the carrots and onions in the same fat to a light brown, drain and add the vegetables to the meat.

Sprinkle flour on to the meat and shake the pan to mix in. Place in a hot oven for approximately 10 minutes.

Add the tomato puree and mix in sufficient stock to just cover the meat. Add the herbs and garlic. Season. Bring to the boil, skim, cover with a lid and place in a moderate oven at 175 °C until three quarters cooked (approximately 1 hour). Remove the meat to a clean pan.

Brown the button onions and mushrooms quickly in a little fat and add to the meat.

Remove the fat from the sauce.

Correct the consistency, seasoning and colour and pass through a fine strainer over the meat and garnish.

Bring to the boil, cover with a lid and replace in the oven at approximately 150 °C to finish cooking gently (approximately 1 hour).

Serve the navarin sprinkled with chopped parsley.

For conventional Chicken Dijonnaise preparation,

Bring sufficient stock to the boil, add the chicken supremes, reboil and skim.

Season lightly with salt and simmer gently until cooked. Place in an earthenware dish, cover and keep warm.

Sweat the onions in the oil, until soft. Add Dijon mustard, sugar, half the cream. Reduce to a coating consistency and pass through a fine strainer into a clean pan. Mix the vermouth and Col-flo and add to sauce.

Finish with the remaining cream. Correct seasoning.

Coat chicken with sauce and serve with rice and vegetables.

Appendix D.2-b Questionnaires used in Experiment 2

i) For Chicken Dijonnaise (2 pages)

Bournemouth University - Thomas Hardy Restaurant

We would appreciate your help by giving us your views on the **main course** you have just eaten. This will help us provide you with a better service in the future.

Are you male or female ? Male ☐ Female ☐

Which is your age group ? Please tick one box only

up to 18 ☐ 18-25 ☐ 26-35 ☐ 36-45 ☐ 46-55 ☐ 56-65 ☐ 66 + ☐

How often do you eat out ? Please tick one box only

Every day ☐ Once a week ☐ Twice a month ☐ Once a month ☐ Six times a year ☐ Once a year ☐ Less than once a year ☐

How often do you eat here at the Thomas Hardy Restaurant ? Please tick one box only

Every day ☐ Once a week ☐ Twice a month ☐ Once a month ☐ Six times a year ☐ Once a year ☐ This the first visit ☐

How much do you agree with the statement below? Please mark on the scale.

I have been looking forward to eating here

Agree strongly | Agree | Neither agree nor disagree | Disagree | Disagree strongly

Your main course was Chicken Dijonnaise

How often do you eat chicken ? Please tick one box only

Every day ☐ Once a week ☐ Twice a month ☐ Once a month ☐ Six times a year ☐ Once a year ☐ Less than once a year ☐

How much did you enjoy the Chicken Dijonnaise ? Please mark on the scale below.

Dislike extremely | Dislike moderately | Dislike slightly | Neither like nor dislike | Like slightly | Like moderately | Like extremely

Please turn over

How close do you think the Chicken Dijonnaise came to being ideal for <u>you</u> ?

Please mark on the scales below for each aspect of the **Chicken Dijonnaise** and the vegetables.

Amount of chicken
Far too little — Perfect — Far too much

Amount of sauce
Far too little — Perfect — Far too much

Amount of vegetables
Far too little — Perfect — Far too much

Size of vegetable pieces
Far too small — Perfect — Far too large

Colour of chicken
Far too pale — Perfect — Far too dark

Colour of vegetables
Far too pale — Perfect — Far too dark

Colour of sauce
Far too pale — Perfect — Far too dark

Texture of chicken
Far too tender — Perfect — Far too tough

Texture of sauce
Far too thin — Perfect — Far too thick

Flavour of chicken
Far too weak — Perfect — Far too strong

Flavour of sauce
Far too weak — Perfect — Far too strong

Now you have considered how your meal might have differed from what you would consider ideal, please consider the following question again.

How much did you enjoy the Chicken Dijonnaise ? Please mark on the scale below.

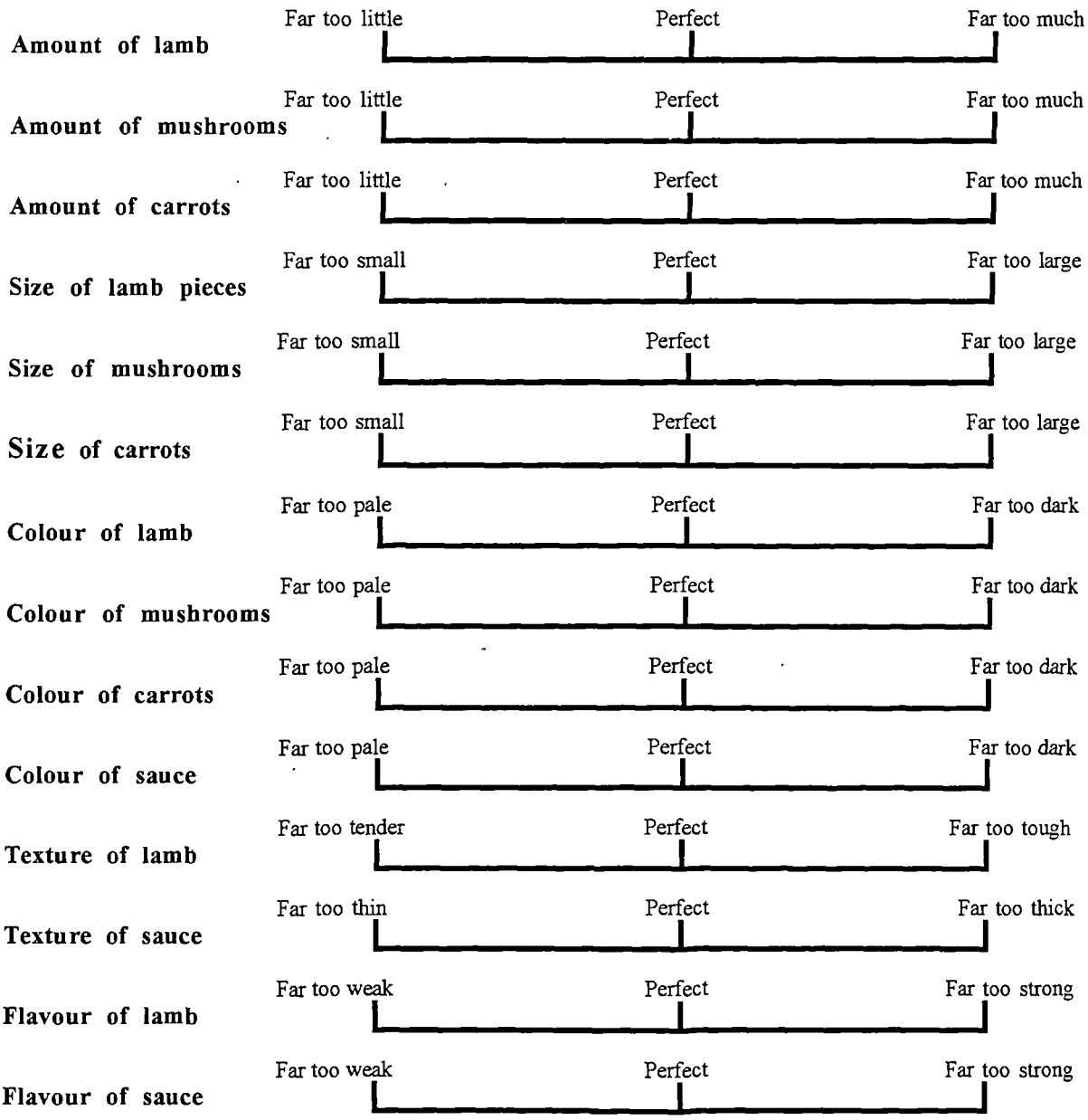
Dislike extremely — Dislike moderately — Dislike slightly — Neither like nor dislike — Like slightly — Like moderately — Like extremely

Thank you for your help.

ii) For Lamb Navarin (First page as for Chicken Dijonnaise)

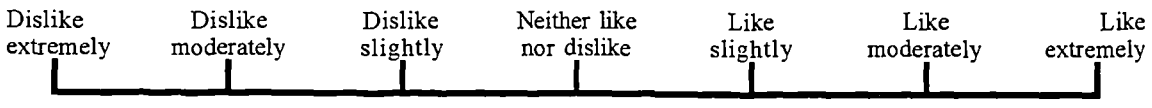
How close do you think the Lamb Navarin came to being ideal for <u>you</u> ?

Please mark on the scales below for each aspect of the **Lamb Navarin**.



Now you have considered how your meal might have differed from what you would consider ideal, please consider the following question again.

How much did you enjoy the Lamb Navarin ? Please mark on the scale below.



Thank you for your help.

Appendix D.3 Questionnaire for Experiment 3 (reduced size)

Questionnaire on attitudes to eating away from home.

This questionnaire relates to foods eaten in restaurants, pubs, fast-food outlets, cafés, canteens, etc.

Are you male or female ? Male ☐ Female ☐

Which is your age group ? Please tick one box only

up to 19 ☐ 20-24 ☐ 25-34 ☐ 35-44 ☐ 45-54 ☐ 55-64 ☐ 65 + ☐

Please tick the box which shows the closest to how often you eat out.

Most days/ twice weekly ☐ At least once a week ☐ Fort-nightly ☐ At least once a month ☐ Less often ☐

What is your occupation or last occupation if not working or retired ?

_____

Using one of the code numbers (1 to 9) from the box below, what action would you normally take for each of the following problems with a meal served to you when eating out ?

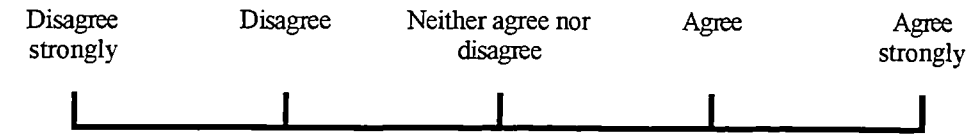
Code Number

1. I feel satisfied so mention nothing to anyone else and do nothing.
2. I feel dissatisfied, mention nothing to anyone else and do nothing.
3. I feel dissatisfied, mention nothing to anyone else but do not finish the meal.
4. I feel dissatisfied, mention the problem to another customer but still finish the meal.
5. I feel dissatisfied, mention the problem to another customer but do not finish the meal.
6. I feel dissatisfied, mention the problem to restaurant staff but still finish the meal.
7. I feel dissatisfied, mention the problem to restaurant staff but do not finish the meal.
8. I feel dissatisfied, mention the problem to restaurant staff and ask for a replacement meal.
9. I feel dissatisfied, mention the problem to restaurant staff and refuse payment for the meal.

Problems with a meal	Write in code number from 1 to 9 (see box)
a The food is not at the correct temperature *e.g. not hot enough, not cold enough, too hot, too cold.*	
b The food is not cooked to my personal requirements *e.g. for meat, rare or well-done, for vegetables, crisp, etc.*	
c The food is not cooked as I expected *e.g. fried instead of roasted, processed not fresh, etc.*	
d The type of food is not what I expected *e.g. the wrong type of meat or fish, etc.*	
e The food is not presented well on the plate *e.g. splashes of sauce or grease, or mixed up items*	
f The food is too highly seasoned for me *e.g. too salty, peppery or spicy*	
g The taste of the food is not acceptable *e.g. off-flavours, rancid, etc.*	
h The balance of individual meal items is incorrect *e.g. too much potato, not enough meat, etc.*	
i The *overall* amount of food served is too little	
j The *overall* amount of food served is too much	
k Other - please specify _____	

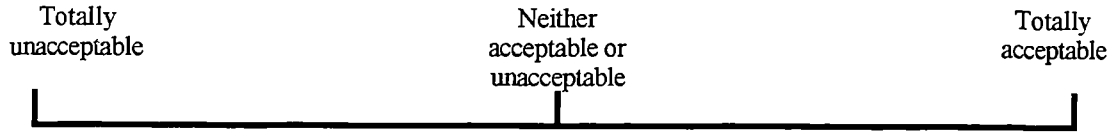
How much do you agree with the statement below? Please mark on the scale.

The way my meal is prepared is important to me.

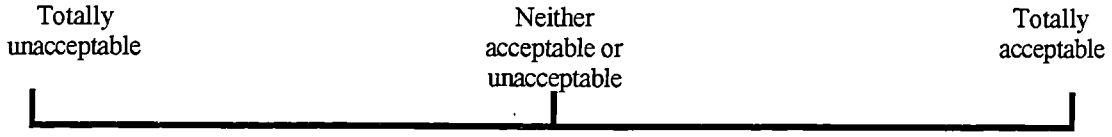


Assuming that the meal in front of you looks as you would expect, how would you rate the meal knowing that it had been prepared in each of the following ways. Please mark the scale according to how **acceptable** it would be to you.

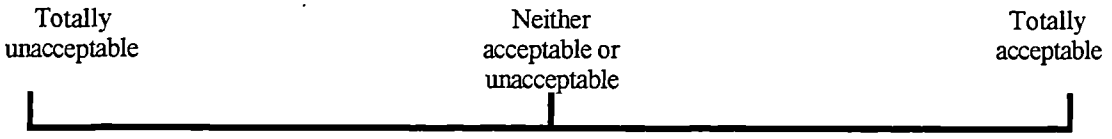
1. The food has just been prepared from raw materials and cooked to order.



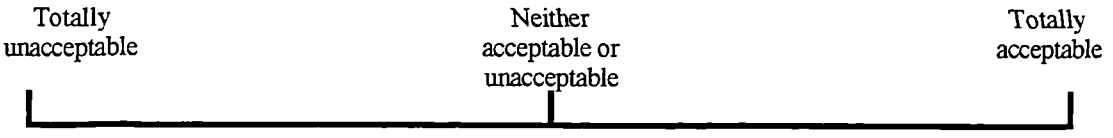
2. The food was previously prepared, cooked, frozen, stored in a freezer and reheated to order.



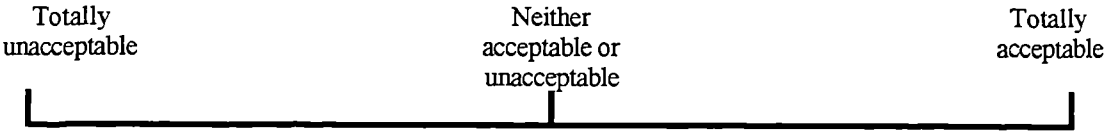
3. The food was previously prepared, cooked, cooled, stored in a refrigerator and reheated to order.



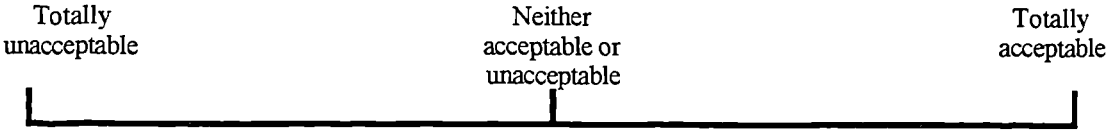
4. The food was previously prepared, vacuum packed in a bag, cooked, cooled, stored in a refrigerator and reheated to order.



5. The food was previously prepared, dried, stored, rehydrated and reheated to order.



6. The food was previously prepared using a mixture of the above methods.



How much do you agree with the statements below? Please mark on each scale.

I am constantly sampling new and different foods

Disagree strongly — Agree strongly

I don't trust new foods.

Disagree strongly — Agree strongly

If I don't know what is in a food, I won't try it.

Disagree strongly — Agree strongly

I like foods from different countries.

Disagree strongly — Agree strongly

Ethnic foods look too weird to eat.

Disagree strongly — Agree strongly

At dinner parties, I will try a new food.

Disagree strongly — Agree strongly

I am afraid to eat things I have never had before.

Disagree strongly — Agree strongly

I am very particular about the foods I will eat.

Disagree strongly — Agree strongly

I will eat almost anything.

Disagree strongly — Agree strongly

I like to try new ethnic restaurants.

Disagree strongly — Agree strongly

When eating out, I will try a new food.

Disagree strongly — Agree strongly

For each of the following, please tick the box according to how **important** the factor is in **giving you pleasure** when you eat out.

Please tick one box only on each line.

	Not Important	Slightly Important	Moderately Important	Very Important	Extremely Important
Appearance of the meal					
Attentive staff during meal					
Attractiveness of menu					
Availability of alcohol					
Comfort of seats					
Decor/lighting of dining room					
Enjoyment of food					
Enjoyment of wine					
Facilities for children					
Facilities for disabled					
Formality of the meal occasion					
Friendliness of staff					
Help from staff when ordering					
Information given on menu					
Language of the menu					
Layout of items on table					
Live entertainment					
Location of the restaurant					
Mood created in dining room					
Overall cost of the occasion					
Presence of children					
Presence of recorded music					
Privacy of your seating					
Range of drinks available					
Range of menu items					
Staff dress					
The farewell from staff					
The other customers					
Time to relax at end of meal					
Type of meal service					
Vegetarian /vegan menu					
Welcome given by staff					
What you wear					
Other (please specify)					

Please think about each of the following activities and then mark each scale according to **how much pleasure** each activity gives you **personally**.

Activity	Pleasure rating Great displeasure — Indifferent — Great pleasure
Going to films, theatre, concerts, etc.	
Drawing, painting, crafts, etc.	
Doing things with the family	
Doing things with friends	
Driving or maintaining cars	
Collecting antiques, stamps, etc.	
Playing computer games	
Cooking for self, family or friends	
Home maintenance & improvements	
Doing nothing	
Having a drink at home	
Going out for a drink at pubs, clubs, etc.	
Eating a meal at home	
Eating out at a restaurant, hotel, etc.	
Gambling - Lottery, horse racing, etc.	
Holidays away from home	
Listening to music - CDs/records/tapes	
Making music - keyboards, strings, etc.	
Reading books, magazines, etc.	
Sexual activity	
Sleeping or dozing	
Smoking - cigarettes, pipe, cigars, etc.	
Participating in sports	
Travelling to new places	
Walking, rambling, etc.	
Watching sport as a spectator	
Watching television	
Working for money	
Working for charity	
Other	
Other	

Please be assured that all information given is anonymous and confidential. Thank you for your help. Please make sure this is returned to Philip Creed, Room D144, Department of Food & Hospitality Management, Bournemouth University, Fern Barrow, Poole, Dorset, BH12 5BB.

Appendix E.1

Factor Analysis of relevant attributes of dishes used in Experiment 2.

Chicken Dijonnaise

Factor Analysis Summary

Number of Variables	6
Est. Number of Factors	3
Number of Factors	3
Number of Cases	36
Number Missing	0
Degrees of Freedom	20
Bartlett's Chi Square	52.273
P-Value	.0001

Factor Extraction Method: Principal Components
Extraction Rule: Method Default
Transformation Method: Orthotran/Varimax

Eigenvalues

	Magnitude	Variance Prop.
Value 1	1.948	.325
Value 2	1.449	.242
Value 3	1.288	.215

Oblique Solution Primary Pattern Matrix

	Factor 1	Factor 2	Factor 3
CoCh	.078	.824	-.363
ClSa	-.077	-.217	.865
TeCh	.913	-.168	-9.180E-7
TeSa	.294	.099	.797
FlCh	-.155	.884	.161
FlSa	.846	.109	.108

In the table above, the attributes are - Colour of chicken (CoCh), Colour of sauce (CoSa), Texture of chicken (TeCh), Texture of sauce (TeSa), Flavour of chicken (FlCh), Flavour of sauce (FlSa) respectively. The anchor words used for each attribute are shown in Appendix D.2-b.

Lamb Navarin

Factor Analysis Summary

Number of Variables	8
Est. Number of Factors	4
Number of Factors	4
Number of Cases	41
Number Missing	0
Degrees of Freedom	35
Bartlett's Chi Square	99.056
P-Value	<.0001

Factor Extraction Method: Principal Components
Extraction Rule: Method Default
Transformation Method: Orthotran/Varimax

Eigenvalues

	Magnitude	Variance Prop.
Value 1	2.416	.302
Value 2	1.838	.230
Value 3	1.191	.149
Value 4	.904	.113

Oblique Solution Primary Pattern Matrix

	Factor 1	Factor 2	Factor 3	Factor 4
CoLa	.850	-.028	.059	.084
CoMu	.295	-.093	-.121	.760
CoCa	-.085	-1.033E-3	.111	.886
CoSa	.850	.130	-1.652E-5	-3.597E-5
TeLa	-.103	.212	.781	.317
TeSa	.140	-.198	.862	-.217
FlLa	-.096	.829	.100	-.280
FlSa	.215	.871	-.124	.126

In the table above, the attributes are - Colour of lamb (CoLa), Colour of mushrooms (CoMu), Colour of carrots (CoCa), Colour of sauce (CoSa), Texture of lamb (TeLa), Texture of sauce (TeSa), Flavour of lamb (FlLa), Flavour of sauce (FlSa) respectively. The anchor words used for each attribute are shown in Appendix D.2-b.

Appendix E.2

Factor Analysis of importance of attributes giving pleasure when eating out, used in Experiment 3.

Factor Analysis Summary

Number of Variables	30
Est. Number of Factors	15
Number of Factors	12
Number of Cases	183
Number Missing	5
Degrees of Freedom	464
Bartlett's Chi Square	2383.727
P-Value	<.0001

Factor Extraction Method: Principal Components
Extraction Rule: Method Default
Transformation Method: Orthotran/Varimax

Eigenvalues

	Magnitude	Variance Prop.
Value 1	7.835	.261
Value 2	2.539	.085
Value 3	1.895	.063
Value 4	1.726	.058
Value 5	1.494	.050
Value 6	1.243	.041
Value 7	1.116	.037
Value 8	1.028	.034
Value 9	1.008	.034
Value 10	.964	.032
Value 11	.858	.029
Value 12	.828	.028
Value 13	.787	.026
Value 14	.694	.023
Value 15	.647	.022

Oblique Solution Primary Pattern Matrix from factor analysis

(Reduced view from Statview print-out)

Oblique Solution Primary Pattern Matrix

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11	Factor 12
Iapp	.280	-.022	-.013	-.010	.135	.142	3.720E-3	.033	.014	-.250	.635	-.152
Iatte	.778	-.053	.074	-.094	.098	-5.345E-3	-.119	.053	-.048	-.039	.191	-.097
Aalc	-.044	.902	.061	-.036	2.128E-3	4.360E-3	-.112	.061	-.056	-.036	-.038	4.861E-3
Icomf	-9.222E-4	.277	-1.707E-4	.224	.502	-.147	-.033	-.062	.101	.077	.194	-.053
Idecor	.148	-.069	-.069	-.088	.710	-.041	.189	.072	-.038	-.035	.161	-.014
Ifood	-2.371E-3	.172	-.219	.122	-.039	-.031	.167	-.091	.019	.083	.616	.259
Iwine	-8.130E-4	.790	-.233	-.079	-.020	1.174E-4	.250	.147	-5.066E-3	-.161	.162	-.075
Idisab	.603	.043	-.237	-.042	.160	.149	.116	.024	.128	-.098	-.528	.020
Iformal	.069	.035	-.095	.456	.057	-.018	.231	.064	.079	-.527	-.184	-.066
Ifriend	.810	-.099	.167	-.085	.096	-.156	-.036	-.028	.016	-4.598E-3	.079	.061
Ihelp	.780	-.083	.072	-.063	-.106	.178	-.022	-.011	.189	-.037	.029	-.088
Iinfo	.398	.041	.029	-.155	-.014	.057	-2.732E-3	-.039	.669	.038	.049	.055
Ilang	.088	.013	.115	.038	-.092	8.028E-3	.054	-.010	.848	.142	-.018	.031
Itable	.259	-.065	-.081	.553	.160	.079	.015	-.083	.190	-.137	.091	-.386
Ienter	6.969E-3	.080	.790	.107	-.158	.083	.253	-.136	.113	-.078	-.100	-.230
Ilocat	5.802E-3	-.034	.223	.033	-.051	.046	.828	-.077	-.033	.147	6.568E-4	-.040
Imood	.014	-1.926E-4	-.054	-.081	.240	-.068	.715	.104	.110	-.024	.054	.144
Icost	5.729E-3	-.013	-.024	-.047	.098	.133	.235	.109	.197	.749	-.135	-.162
Ichild	.098	.066	.052	.228	-.046	.076	.012	.822	-.066	.074	-.037	5.164E-5
Imusic	.025	.061	.704	-.153	.254	.024	-.048	.254	.023	.077	-.024	.251
Iprivat	-.034	.105	.111	074	.813	.147	-.026	-.075	-.099	.061	-.180	.026
Idrink	-.139	775	.218	.085	.120	2.147E-3	-.076	-.161	.086	.147	-.045	046
Idress	.149	-.046	-6.347E-4	.585	.122	-.227	-.151	.221	.126	.167	.159	.028
Ifarewl	.769	.114	-.122	.180	-.081	-.069	-5.992E-3	.071	8.657E-5	.062	-.079	.056
Icust	.141	.148	6.094E-3	.761	-.246	.056	.070	-.092	-.500	.159	.068	.040
Irelax	.253	.067	.057	.426	.104	.065	-.025	-.341	-.117	-4.955E-4	.048	.353
Iservc	.184	-.016	-.042	.066	-.016	.062	.067	.060	.135	-.187	.033	.689
Iveg	-.013	-2.124E-3	.078	-.075	.032	.917	-6.338E-3	.073	.048	.100	.044	.029
Iwelcm	.858	-.039	-.048	.045	-.064	-.033	.125	-.082	-.109	.121	-.107	.118
Iwear	-.217	-.055	.066	.745	.071	-.026	-.033	.247	.070	-.190	-.027	.124

Key to abbreviations

Abbreviation	Variable
Iapp	Appearance of the meal
Iatte	Attentive staff during meal
AAlc	Availability of alcohol
Icomf	Comfort of seats
Idecor	Decor/lighting of dining room
Ifood	Enjoyment of food
Iwine	Enjoyment of wine
Idisab	Facilities for disabled
Iform	Formality of the meal occasion
Ifriend	Friendliness of staff
Ihelp	Help from staff when ordering
Iinfo	Information given on menu
Ilang	Language of the menu
Itable	Layout of items on table
Ienter	Live entertainment
Ilocat	Location of the restaurant
Imood	Mood created in dining room
Icost	Overall cost of the occasion
Ichild	Presence of children
Imusic	Presence of recorded music
Iprivat	Privacy of your seating
Idrink	Range of drinks available
Idress	Staff dress
Ifarewl	The farewell from staff
Icust	The other customers
Irelax	Time to relax at end of meal
Iservc	Type of meal service
Iveg	Vegetarian /vegan menu
Iwelcm	Welcome given by staff
Iwear	What you wear

Appendix E.3

Factor Analysis of perceived pleasure derived from several activities, used in Experiment 3.

Factor Analysis Summary

Number of Variables	23
Est. Number of Factors	11
Number of Factors	11
Number of Cases	165
Number Missing	23
Degrees of Freedom	275
Bartlett's Chi Square	1081.899
P-Value	<.0001

Factor Extraction Method: Principal Components
Extraction Rule: Method Default
Transformation Method: Orthotran/Varimax

Eigenvalues

	Magnitude	Variance Prop.
Value 1	3.957	.172
Value 2	2.642	.115
Value 3	2.165	.094
Value 4	1.628	.071
Value 5	1.369	.060
Value 6	1.283	.056
Value 7	1.087	.047
Value 8	.942	.041
Value 9	.923	.040
Value 10	.827	.036
Value 11	.790	.034

Oblique Solution Primary Pattern Matrix from factor analysis
(Reduced view from Statview print-out)

Oblique Solution Primary Pattern Matrix

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10	Factor 11
Afilms	-.099	-.021	-.163	-.033	.356	-.144	-1.613E-3	-.328	.070	.133	.623
Afriend	.218	-.120	.042	.043	.785	-.065	.116	-.013	-.057	-.023	.215
Acars	.104	-.072	-1.389E-3	.032	-3.780E-3	.027	-.026	.853	.102	.031	-.044
Acomp	.719	.047	-.073	.224	.016	-.054	.028	.118	1.670E-3	.086	.026
Acook	.119	.044	.647	.188	-.043	.061	.225	-.310	.028	-.145	-2.519E-3
Ahome	-8.730E-3	-.075	.880	-.079	.116	-.025	-.163	.143	-.054	.090	-.020
Anothng	.102	.079	-.046	.799	-.122	.038	-.121	-.093	.160	1.232E-3	4.809E-3
Admkhm	-.107	-.069	-.025	.163	.020	.882	-.019	-.024	-.039	.151	-.070
Admkout	.114	.101	-.101	-.128	.181	.621	-.149	.213	-.142	.062	.218
Aeathm	.071	-.043	.268	-.107	-.163	.567	.392	-.118	.236	-.242	-.035
Aeatout	-.093	.186	.074	-6.107E-3	.812	.130	-.029	.025	.098	-.116	-.195
Agamb	.802	2.264E-3	.145	-.092	.013	-.036	-.044	9.357E-3	.030	.159	-.054
Aholid	.143	.905	-.016	4.435E-3	7.882E-3	-.049	-.046	-.055	2.868E-3	-.039	-.010
Alismus	.015	.148	.076	8.443E-3	-.102	.091	-.146	.074	.074	-.022	.874
Aplmus	.060	.014	-.104	.113	-.186	.034	.469	.308	-.516	-.119	.399
Aread	-.140	.082	-.031	.136	.347	-.065	.543	-7.230E-3	-.084	.123	.057
Asleep	-.070	-.077	.052	.847	.165	-8.392E-3	8.204E-3	.108	-.082	1.135E-3	-.033
Asport	.043	.124	-9.405E-3	-.156	.054	5.540E-3	.029	.135	.114	.735	.039
Atrav	-.146	.830	-2.805E-3	-.017	.048	.030	.085	-.016	-.028	.012	.051
awalk	-.550	.204	.458	-.017	-.013	-.178	.249	.081	.058	.180	.059
Awsprt	.130	-.105	.020	.117	-.134	.083	.033	-.115	-.057	.853	-.018
Awmoney	.028	-.039	-.017	.119	.013	-.044	.153	.169	.843	.021	.143
Awchar	3.715E-5	.028	-2.701E-3	-.157	.024	.029	.821	-.044	.104	046	-.177

Key to abbreviations

Abbreviation	Activity
Afilms	Going to films, theatre, concerts, etc.
Afriend	Doing things with friends
Acars	Driving or maintaining cars
Acomp	Playing computer games
Acook	Cooking for self, family or friends
Ahome	Home maintenance & improvements
Anothing	Doing nothing
Admkhm	Having a drink at home
Admkout	Going out for a drink at pubs, clubs, etc.
Aeathm	Eating a meal at home
Aeatout	Eating out at a restaurant, hotel, etc.
Agamb	Gambling - Lottery, horse racing, etc.
Aholid	Holidays away from home
Alismus	Listening to music - CDs/records/tapes
Aplmus	Making music - keyboards, strings, etc.
Aread	Reading books, magazines, etc.
Asleep	Sleeping or dozing
Asport	Participating in sports
Atrav	Travelling to new places
Awalk	Walking, rambling, etc.
Awsprt	Watching sport as a spectator
Awmoney	Working for money
Awchar	Working for charity

Appendix F. Overview of statistical and sensory evaluation techniques used

Statistical techniques

Analysis of variance (ANOVA)

This test is used for comparing three or more groups. Bower (1997) describes it as comparing 'variability between treatments with that within treatments'. The technique calculates two estimates of the population variance based on these two sources, between and within treatments. The mean squares from these two groups are compared to the mean square for the error, the residual variation which cannot be accounted for by the treatment or factor effects. The ratio of these mean squares is the F statistic which is looked up in tables of the F distribution under the degrees of freedom for treatments and error. If the critical value is exceeded, then a significant difference exists between at least two of the mean values. A high value of F will be obtained when the variability between treatments is high but the variability within treatments, i.e. good agreement, is low. Once a significant F statistic has been found, the location of the differences is found using the *post hoc* tests (q.v.). ANOVA assumes that the distribution of values within means is normal and has been widely used in many areas of scientific research as the basic version can be adapted to study the effect of factors at various levels for many types of experimental design. The technique was used in this work as the most suitable for comparing mean values of various sensory data.

Chi squared (χ^2)

This statistic is used to determine if individual numbers in a two way table of two nominal variables are significantly different from what would be expected from the distribution of row and column totals. For each cell, the difference between the observed and expected value is squared and then divided by the expected value. The sum of all these values is the χ^2 statistic. This is looked up in the χ^2 distribution table for n-1 degrees of freedom. If this value exceeds the critical value from the table, this means there is a significant difference in the interaction between the two variables under study.

or $$\chi^2 = \sum\left[\frac{(O-E)^2}{E}\right]$$

where O = observed frequency and E = expected frequency

To locate the cells which are causing the significant difference, the *post hoc* cell contributions are calculated. These are a from of standardised residual showing what each cell contributes to the overall statistic. They follow a normal distribution. So an absolute value of 1.96 or more indicates significance at $p = 0.05$ or less. A positive sign means the cell number is significantly higher than expected, a negative sign indicates a significantly smaller number than expected. The method was used in this work to analyse the distribution of responses to the survey regarding demographic groups.

Correlation coefficient (r)

This statistic indicates the degree of linear association between two variables. It takes a value between +1 and -1. A value of 1 indicates that large values of one variable are exactly associated with large values of the other variable. A value of -1 indicates that large values of one variable are exactly associated with small values of the other variable. A value of 0 indicates that there is no association between the two variables. The coefficient is calculated from:-

$$r = \frac{n\sum x_i y_i - \sum x_i \sum y_i}{\sqrt{\left(n\sum x_i^2 - \left(\sum x_i\right)^2\right)\left(n\sum y_i^2 - \left(\sum y_i\right)^2\right)}}$$

Where Σx_i, Σy_i, Σx^2, Σy^2, $\Sigma x_i y_i$ are the sums of x, y, x^2, y^2 and xy respectively and n is the number of pairs of data. In this work, comparing liking before and after assessing detailed sensory attributes was the most suitable method to measure association.

Factor Analysis

This multivariate technique aims to explore the structure of a number of variables with data in matrix form. It determines the correlations between the variables, grouping those which behave in a similar manner into a number of factors. This means that the data can be reduced to factors which have an underlying common element leading to a more holistic understanding of the data structure. The technique calculates Eigen values from the data matrix, a common criterion being to extract factors with Eigen values of one or more. Another criterion for extraction is to continue to extract factors until a certain percentage of variance has been accounted for. Hair et al. (1995) quote this percentage as 95 % for the natural science but only 60% for the social sciences where information is less precise. Factor analysis uses rotation of factors in order to optimise the extracted factors so that the variables which make them up have correlations (factor loadings) either near zero or nearer to 1. This upper level depends on how many samples are involved, e.g. for a sample size of 50 a factor loading of

0.75 is needed for significance at the 0.05 level whereas for a sample size of 200, the level is 0.40 (Hair *et al.* 1995). Essentially, factor analysis reduces data to a smaller number of factors which are ranked in order of their ability to explain the numerical variance in the data matrix, thus explaining the data structure, in this work those factors explaining the pleasure of eating out.

Kruskal Wallis

When the data is non-parametric, i.e. it cannot be assumed that the measurement intervals are equal so the assumption of a normal distribution cannot be justified, ANOVA cannot be used. In this case, the Kruskal Wallis test (equivalent to a one-way ANOVA) can be used to compare differences between three or more groups of data. It ranks the pooled data and then for each group or treatment calculates the total of these ranks and from these the treatment mean ranks. It compares the variability between treatments with the overall variation to produce a test statistic, H, which is looked up in the χ^2 distribution table for n-1 degrees of freedom to give an associated probability that the means are the same. In this work, the Intolerance index scores could not be considered as parametric data, so the Kruskal Wallis test was used to compare the mean ranks of the groups of data.

Paired t-test

This test is used where two measurements have been obtained from the same individual. It hypotheses that the mean of the difference between the two values is zero and gives a probability of the mean difference occurring by chance. If this probability is small, say, less than 0.05 or 0.01, there is a statistically significant difference between the two means. If there are n pairs of data and $\overline{D}$ is the mean difference between pairs, the standard error of $\overline{D}$ is $\frac{s_D}{\sqrt{n}}$ so that t, the test statistic is given by $\frac{\overline{D}-D}{SE}$ where D is the hypothesised difference, say, zero. The value of t is then looked up in tables for n-1 degrees of freedom to determines if it exceeds the critical value for the given level of significance.

***Post hoc* tests**

These tests are used when a significant F statistic has been found using ANOVA. They are used to determine which particular means are significantly different from other mean values. As the groups being analysed may be of different sizes and have different variances, several *post hoc* tests have been devised depending on these factors. Selection will also depend on personal preference, the balance between

conservative and liberal tests or the need for a specific confidence interval. Examples of these tests are:-

- Fisher's Protected Least Significant Difference Test - one of the most liberal of *post hoc* tests which may find differences which may not be real, i.e. a type 1 error.
- Scheffé's F-Test - is resistant to violations of the assumptions typically associated with multiple comparison procedures. It is one of the more conservative tests but its robustness has made it popular.
- Bonferroni/Dunn Test - more liberal than Scheffé's F-test but more conservative than Fisher's Protected Least Significant Difference test.

In this work, Scheffé's F-Test was used as many groups of values being compared were of unequal number and variance. Its more conservative assumptions also avoided type 1 errors.

Sensory Evaluation techniques

Duo-Trio

This discrimination test provides the assessor with three samples, one marked as the reference. The assessor has to pick one of the remaining samples which is most dissimilar to the reference sample (Amerine *et al.* 1965; Stone and Sidel 1993) or most similar to the reference sample (Lawless and Heymann 1998). In both cases, if there is no perceptible difference, the probability of guessing correctly in the long run is 0.5. If there is a difference, p will be greater than 0.5. The Duo-Trio test was chosen in this work because, psychologically, it is a more simple test for assessors than the triangle test where three unknowns are grouped. In this work, the assessor was also asked to describe the nature of the difference between the reference and the dissimilar samples.

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