FACTORS AFFECTING THE QUALITY AND SHELF-LIFE OF COOKED CHILLED FOODS WITH SPECIAL REFERENCE TO FULL MEAL VENDING

by

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A thesis submitted to the

Council for National Academic Awards

for the degree of Doctor of Philosophy

Department of Catering and Hotel Administration

Dorset Institute of Higher Education

April 1986

PREFACE

The studies described in this thesis were carried out in the Department of Catering and Hotel Administration, Dorset Institute of Higher Education, between September 1982 and October 1985. No part of this work has been presented as a thesis to any other examining body. Except where stated, the work was carried out unaided.

I wish to thank Dr. A.Youngs, Dr. N.Light and Dr. R.Tomlins for their advice and encouragement in acting as supervisors throughout the course of this work. I am grateful for the support and advice of my colleagues in the Food Science Division in which the research was carried and also for the time and effort contributed by the voluntary members of the taste panels.

I should also like to thank Dr. H.Macfie of the Food Research Institute, Bristol for his advice and generosity in aiding the work involving Prefmap analyses.

The financial support of the Ministry of Agriculture Fisheries and Food and also the Dorset County Council is gratefully acknowledged.

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by HELEN YOUNG

ABSTRACT

A nation wide survey of the vending industry indicated that the shelf-life of chilled menu items served from vending machines rarely exceeded 24 hours. This necessitated food production and distribution to vending sites on a daily basis. The short life coupled with unpredictable consumer demand may result in high food wastage rates.

Vacuum and modified atmosphere packaging (MAP) are known to improve stored raw food quality. In order to optimize the quality and shelf-life of vended foods, the effects of these techniques and length of storage time on menu items were studied. Chicken drumsticks and chicken a la king were either individually cling wrapped, vacuum packed or packed under modified atmosphere (70% CO_2, 30% O_2) and stored for up to 21 days in a chilled food vending machine.

The growth of naturally occurring micro-organisms was delayed in vacuum packed samples, compared with cling wrapped samples. However, direct inoculation studies indicated that this effect was dependent on the nature of the initial microflora. The public health risk of serving cooked food from vending machines was assessed by means of a survey of the operating temperatures of chilled food vending machines and a review of the growth characteristics of the major food poisoning micro-organisms. The surveyed machines were able to maintain temperatures below 5°C, although this temperature was not universally found.

The sensory quality of the chicken samples was examined by two trained taste panels and also a consumer panel. Stepwise discriminant analysis of the trained panel scores indicated that packaging and length of storage had a distinctive and unique effect on the sensory quality of both products. The mean consumer scores were used to construct significant ($p<0.05$) regression models, which showed that on average consumers preferred the fresh unpackaged sample and least preferred the cling wrapped samples. However, when the consumer scores of individuals were examined by means of Prefmap analysis, subgroups were found to exist within the population that held polar viewpoints in opinion.

The results show that MAP and vacuum packaging may be used in place of cling wrapping to extend the shelf-life of certain vended menu items, but of more immediate importance to the vending industry is the implementation of proper temperature control to ensure a hazard free system.

CHAPTER 1

INTRODUCTION

1.1 Full meal vending

1.1.1 Definition

Full meal vending is an automated method of foodservice. Individual items or complete meals are stored in a chilled food vending machine (C.F.V.M.) and purchased automatically by the consumer, if necessary, the consumer may reheat the purchased food in a microwave oven.

In the U.K. cooked food vending has been limited to place of work feeding, particularly to shift workers in factories, hotels, hospitals, police and fire stations and also for workers based in isolated sites. According to the recent Industrial Society survey of 'Catering Prices, Costs and Subsidies' (1984) 76% of companies now vend drinks and 46% vend morning and afternoon snacks. Vending may either supplement a traditional form of foodservice or may be the only method of foodservice available for all staff.

1.1.2. Historical background

Vending cooked foods is not a new phenomenon; Ginsberg (1963) described the packaging requirements of cooked vended food in America; packaging for vended food should serve as a portion control dish, a freezing container, a shipping tray, a heating utensil, a point-of-purchase display, a serving dish and a dining plate. In the U.K. one of the first chilled food vending systems accompanied by microwave reheating was operated by the British Automatic Company in 1966 (Skinner, 1985). Significant growth in the U.K. has only begun over recent years, as its major advantages of providing a 23.5 hour service (30 minutes should be allowed for cleaning and loading the machine), with the minimum of food service staff

has been realized (Euromonitor, 1984). As a whole, the vending industry has weathered the recent recession better than many other sections of British industry and there are considerable prospects for growth, particularly in servicing the manufacturing and the white collar work sectors of industry (I.C.C. Business Ratio's Report, 1985; Euromonitor, 1983). The Geneva Institute of Research maintain there are 380,000 possible locations for vending food and or drink in the U.K., yet only 60,000 (16%) are being utilized (Euromonitor, 1984). If the vending industry can exploit this potential then the future is one of expansion.

Cooked meal vending constitutes a very small proportion of the total vending industry; the most recent research showed that only 2% of the population who use vending machines have ever purchased hot or cold meals through a vending machine and only 3% have purchased snacks such as sandwiches (N.O.P.; 1982). However, it represents one of the largest growth areas within the vending industry (Euromonitor, 1983).

1.1.3. Vending as a catering system

As a method of food service, cooked meal vending needs to be linked to a system of food production. The major catering food production systems available are listed in Figure 1.1.

Figure 1.1. Catering Food Production Systems Available
(adapted from Glew, 1985)

Conventional	1	Cook
Cook-Chill	2	Cook--->Chill-->*-->Heat-->Serve
Cook-Freeze	3	Cook--->Freeze->*-->Heat-->Serve
		↓
	4	Thaw--->*-->Heat-->Serve
Total convenience	5	Canned
	6	Dehydrated-Reconstitute-Heat->Serve
	7	Frozen
	9	Prepared->raw->Cook

*at this stage the chilled cooked foods may be stored in a refrigerated food vending machine.

Various permutations of catering systems described in Figure 1.1 have been used in conjunction with vended food service and are listed in Table 1.1.

Table 1.1 Types of cooked food vending

Method	Type of catering system
Chilled foods held in a CFVM may be reheated by the consumer in a microwave oven	Cook-chill Cook-freeze thaw Total convenience;frozen thawed
Preheated foods served hot from the vending machine	Conventional
Canned foods held hot in a vending machine	Total convenience; Canned
Raw prepared foods cooked as required by the vending machine e.g. toasted sandwiches, chips	Total convenience; Prepared

Chilled food are the most frequently found method of food production in British food vending systems partly because the majority of vending machines are designed to hold

food at chill temperatures rather than frozen or hot. For this reason and because storage of cooked foods at chill temperatures is potentially hazardous both microbiologically and organoleptically, the cook chill vend (CCV) system will be focussed on for the rest of this study.

Foods cooked according to cook-chill principles are not sterile and are stored at temperatures that tolerate some microbial growth, therefore according to D.H.S.S. Guidelines (1980) their shelf-life is limited to 5 days. Other recommendations of the D.H.S.S. Guidelines (1980) include the rapid chilling of cooked food to 3°C within two hours of completion of cooking (which is only possible with rapid chilling equipment such as a blast chiller). A summary of the cook-chill process as recommended by the D.H.S.S. Guidelines (1980) is shown in Table 1.2

Table 1.2 The cook-chill process(D.H.S.S. 1980)

Operation	Temperature constraints	Time constraints
Initial cooking	>70°C	
Portioning	<10°C	<30 minutes
Rapid chilling	< 3°C	<90 minutes
Refrigerated storage	0-3°C if between 5-10°C consume within 12 hours. If greater 10°C discard	<5 days
Distribution	For short periods insulated containers suffice. For longer periods refrigerated transport is required.	
Refrigerated storage	0 - 3°C	
Reheating	>70°C	

1.1.4 The unique aspects of chilled food vending

In comparison with other catering systems, the unique aspects of chilled food vending are the refrigerated storage of individually packaged food items in a chilled food vending machine, the direct automated purchase of items by the consumer and the possibility of the consumer reheating the purchased food. The storage of cooked food in a CFVM represents an additional stage in the food production cycle, thus increasing its complexity by introducing further processing parameters. The parameters of storage unique to chilled food vending, are the temperature of storage within the CFVM, the length of storage time, the packaging and the lighting. The present work deals with the effect of the complete production cycle associated with vended storage on product quality. The purpose of the rest of this chapter is to examine the literature relating to the production stages found in a cook-chill vend system and indicate the effects processing parameters may have on product quality.

1.2. Factors affecting food quality

1.2.1. Introduction

There are several aspects of product quality; the public health risk due to food infections, foodborne disease and transmission of non microbiological toxins; the nutritional quality; microbiological and non-microbiological food spoilage and consumer acceptability. As one of the major limitations on microbial growth is temperature, then the rate and degree of microbial growth in foods is directly affected by the temperature history the food experiences. Temperatures should be below the range which allow the growth of most pathogens. This should be manipulated in order to prevent the development of potentially dangerous populations of pathogenic organisms.

Once microbiological safety has been ensured, then other quality aspects may be considered; in particular the sensory characteristics and consumer acceptability. Many raw foods have optimum storage temperatures, below or above which the sensory quality deteriorates at a faster rate. For example, storage of fruits and vegetables below their optimum can result in chilling injury, which is a disorder induced by low but non-freezing temperatures. The symptoms of chilling injury are discolation, pitting, enhanced microbial storage and inability of immature fruits to ripen (Campbell-Platt, 1985).

Table 1.3 Recommended storage temperatures for some fruit and vegetables
(Campbell-Platt, 1985)

0°- 2°C	7°- 10°C	12°C
Prepared, prepacked salads	Melon	Bananas
Leeks	Passion fruit	Grapefruit
Mushrooms	Peppers	Aubergine
Bean sprouts	Citrus	Lemon
Soft fruit		

Certain quality aspects of cooked foods may also be temperature dependent; the occurrence of rancidity in cooked meats, with the development of a characteristic warmed over flavour is greater at chill storage temperatures than temperatures below freezing (Jakobsson and Bengtsson, 1977; Pearson et al., 1977). Thus undesirable microbial growth and sensory changes may be controlled by modifying the immediate external environment of the food (for example, the temperature of storage or the atmosphere) both within the vending machine and within the packaged food.

1.2.2. Microbiological quality

The growth of food spoilage micro-organisms presents one of the major limitations on shelf-life of foods and the growth of foodborne pathogens presents an ever-present public health risk. There are two types of microbiological investigation of foods; first the study of the naturally occurring microflora of foods and its behaviour under different conditions and second, direct challenge studies, concerned with bacterial inoculation of foods, particularly with pathogenic forms. In this section the effect of the various processing stages of the cook-chill system on the microbiological quality of cooked foods will be considered, followed by a review of the studies of the naturally occurring microflora in foods prepared by cook-chill methods.

1.2.3. The effect of the processing stages of cook-chill on the microbiological quality of foods.

1.2.3.1. Initial cooking

Inadequate combinations of time and temperature during cooking have contributed to outbreaks of foodborne disease (Table 1.4). Raw foods are contaminated with pathogenic micro-organisms. Although many bacteria may be found on a fresh raw food, only a very few if any are potentially harmful to man and generally less than one in a hundred are involved in spoilage (Barnes, 1976).

As most micro-organisms may be killed by heat (thermal processing) the D.H.S.S. (1980) recommend the initial cooking should ensure the destruction of the vegetative stages of any pathogenic organisms present (Table 1.2). Unklesbay et al.(1977) recommend raising the internal temperature of the food to 60°C during initial cooking and then again to at least 73°C during reheating, in order to balance the two heat treatments to ensure optimal sensory quality. In the CCV system the certainty of significantly reducing microbial

numbers during reheating is reduced as it may be difficult to ensure that the consumer reheats the food according to instructions, unlike other cook-chill situations where the caterer has control over the reheating operation. Therefore sufficient heat processing must be applied during initial cooking.

After initial cooking the microbial flora of a cooked food would consist of heat resistant species which have survived the cooking process. In a study by Patterson and Gibbs (1975) chickens were cooked, until all part of the carcasses reached and maintained 85^{o}C for at least 50 minutes. The total plate counts were less than 3-14 x 10^{3}/g and the predominant residual species were Bacillus subtillis and Clostridium bifermentans which are heat resistant sporeformers. Non-sporing bacteria were not detected after cooking. Organisms, which survive heat processing are likely to have a minimum temperature for growth which exceeds subsequent chill storage temperatures. The minimum temperature for growth of an organism may be regarded as the point when either the lag period or the generation time become infinite (Ingram and Mackey, 1976). An additional factor to consider is that the minimum temperature for growth of some strains of bacteria is raised with increased cell damage brought about by heating (Beuchat and Lechowich, 1968).

1.2.3.2 Portioning

On completion of cooking, foods may be portioned and packed. The D.H.S.S. (1980) recommend that this process should not exceed 30 minutes, in order to minimize the length of time the food is left at temperatures above 5^{o}C. The depth of any container used to cool food in, should be restricted to 5 cms. in order to achieve a more rapid reduction in temperature.

The handling of large meats, i.e. roasted meats and poultry, presents a problem as adequate reduction of temperature is difficult to achieve within two hours. A pre-cooling process prior to slicing may be adopted.

The post cooking contamination of cooked foods as mentioned above may be minimized by isolating the portioning/packaging area and reducing the ambient temperature to 10°C. Contamination may be from a number of sources; food handlers, contact with raw foods, cloths, equipment, work surfaces and the air. Hygienic practices should reduce the contamination to non pathogenic types. The composition of the microbial contaminants depends largely on the contaminating source and so it may vary considerably and is difficult to predict. Bomar (1981) demonstrated that psychrophilic and psychrotrophic bacteria are eliminated by the cooking process but that they may plan an important role as contaminants introduced after the cooking process. Tompkin (1973) suggested that the limiting factor for refrigerated shelf-life was recontamination with psychrotrophs after the initial heat treatment. Results from a range of studies are described in Section 1.3.

1.2.3.3. Packaging

If a food is packaged a micro climate is soon established around the food within the pack. Numerous reports are available in the literature of the effect of packaging on the shelf-life of fresh foods and also the inhibitory effect on common spoilage organisms of reduced atmospheric O_2 levels and high levels of CO_2 at chill temperatures. The packaging employed in cook-chill operations is generally limited to air permeable films.

1.2.3.3.1. The importance of packaging film permeability

According to Mead (1983) the most important property of a packaging film is its permeability to O_2 and CO_2. Cling wrap film is water impermeable and gas permeable, whereas films used for MAP and vacuum packaging tend to have far lower gas transmission rates. The O_2 permeability of packaging film is affected by the film composition, storage temperature and humidity. At 3 - 5 ^{o}C the O_2 transmission rates are only 5 - 15% of those at 25 ^{o}C . Humidity also affects the O_2 transmission rate, but the effect is less marked at 3 - 5 ^{o}C than at 25 ^{o}C (Eustace, 1979). Transmission rates are generally reported at 20^{o}C. Nielsen (1983) examined the influence of gas permeability of packaging film on the development and composition of the microflora of vacuum packed bologna type sausage. At 2 ^{o}C both the aerobic plate count and counts of Brochothrix thermosphacta rose to higher numbers in the most permeable film, but after two weeks all bacterial numbers exceeded 10^6 /g. Gram positive cocci constituted the largest portion of the microflora at the beginning of storage, but were quickly overgrown, especially by Brochothrix thermosphacta. This was fastest in the less permeable packaging film. Reduced gas permeability had a positive effect on the development of lactic acid bacteria.

1.2.3.3.2 Modifications in the gaseous atmosphere during storage.

Whatever the film composition, all packaging materials will modify to some extent the gaseous environment of a raw food held under chill conditions as O_2 is consumed by tissue respiration and the metabolic activities of micro-organisms and CO_2 is produced (Brecht, 1980). The volume of CO_2 within a pack is further affected by solubilization into the cut surface fluids and adsorption to amino acid residues. Solubilization of CO_2 may be increased at chill temperatures as the solubility of gases is increased

at low temperatures. Mitsuda et al. (1975) found that 100 - 1000 ul of CO_2 was adsorbed at 25 ^{o}C in 24 hours/g purified proteins. The adsorption was specific to CO_2 and more CO_2 was adsorbed with decreasing moisture content of the protein.

Seideman et al. (1979a) found a significant decrease in the volume of CO_2 occurred in beef packed in 100% CO_2, between the 7th and 14th day of storage. The losses were attributed to either film permeation, dissolution of gases into the meat, binding of CO_2 to meat proteins or going into solution in the meat tissue.

The solubility of CO_2 in white fish tissue has been found to cause a lowering of pH, which produced increased drip. This may be overcome by reducing the CO_2 concentration to 60% or below (Mills, 1985).

1.2.3.3.3 The effect of O_2 and CO_2 concentration on microbial growth.

In the absence of O_2, microbial growth is limited to anaerobes and facultative anaerobes. The presence of CO_2 may further stimulate or inhibit microbial growth. Numerous investigations into the effect of storage atmosphere on the naturally occurring microflora have been reported in the literature, recent examples relating to meat products are given in Table 1.4. The effect of CO_2 on microbial growth and food quality has been reviewed by Daniels et al., (1985).

Table 1.4 Studies into the effect of gaseous atmosphere on microbial growth in fresh meats.

Type of meat	Gaseous atmosphere: Increased CO_2	Vacuum	Increased N_2
Beef		Pierson et al., 1970; Erichsen & Molin, 1981; Seideman et al., 1976; Seideman et al., 1979b; Egan et al., 1979	
Pork	Christopher et al., 1979; Spahl et al., 1981; Blickstad et al., 1981; Blickstad & Molin, 1983	Silliker et al., 1977; Zamora & Zaritzky, 1985	Christopher et al., 1979
Lamb		Henry et al., 1983	
Veal		Lee et al., 1983	
Poultry		Arafa & Chen, 1976; Barnes et al., 1979; Bailey et al., 1979; Jones et al., 1982	Sander & Soo, 1978; Thomas et al., 1984
Various fresh meats	Silliker et al., 1977 (pork & beef); Christopher et al., 1980 (beef, pork and lamb)	Hess et al., 1980 (beef, pork and veal)	

According to Gill and Tan (1980) the most important gram positive groups of bacteria involved in food spoilage are facultative or strict anaerobes (Enterobacter,

Brochothrix thermosphacta, Lactobacilli, Aeromonas and Yersinia) and are apparently not inhibited by CO_2, whereas the most important Gram negative organisms (Pseudomonas) are strict aerobes and are susceptible to CO_2 inhibition. For example, Pseudomonas, an obligate aerobe, was not inhibited until the O_2 concentration was less than 0.8% in the absence of CO_2, but when 10% CO_2 was present the growth of Pseudomonas was halved. In contrast, lactic acid bacteria and Brochothrix thermosphacta were unaffected by 10% CO_2 and the lactic acid bacteria grew at the same rate in the presence or absence of O_2 (Shaw and Nicol, 1969). Maximum inhibition by CO_2 does not totally prevent growth but occurs at comparitively low concentrations of CO_2 (20%) (Gill and Tan, 1980).

Despite CO_2 inhibition of strict aerobes, the microbial composition may be unaffected by CO_2. Gill and Tan (1980) found no significant change in the microbial composition of meat stored in air and 80% air and 20% CO_2 at 3 ± 0.5°C, which had previously been inoculated with Pseudomonas, Acinetobacter, M.thermosphactum, Alteromonas putrefaciens and Yersinia enterocolitica because at chill temperatures the CO_2 inhibited growth rates of Pseudomonas still exceeded the unaffected growth rates of M. thermosphactum and Enterobacter.

The presence of CO_2 reduces the aerobic growth rates of gram negative spoilage organisms by 25 - 30 %, which gives a similar increase in shelf-life. This may be further increased if CO_2 is applied before growth commences, as this causes an extended lag phase in addition to a reduced growth rate (Gill and Tan, 1980). Sander and Soo (1978) found the lag phase of aerobes was extended by 8 - 10 days by the addition of CO_2 to the storage atmosphere of fresh chickens. Hess et al. (1980) found the lag phase for total aerobic organisms lasted on average twice as long in the presence of CO_2 as in air. But if the spoilage flora of raw meat was allowed to adapt to its environment, prior to modified atmosphere packing, it would not exhibit a lag phase

after the application of a protective gas. They recommended packaging immediately after the freshly cut meat surfaces had been unavoidably contaminated by deboning and cutting up.

The basis of the inhibitory effect of CO_2 has not been elucidated fully but may be caused by the direct inhibition of the enzymes of oxidative metabolism, as respiration as well as growth is inhibited (Gill and Tan,1980).

1.2.3.3.4. Post-packaging effect of storage in atmospheres containing CO_2.

A post-treatment effect of CO_2 containing atmospheres, where the rate of microbial growth has been reduced subsequent to modified atmosphere storage in CO_2 enriched atmospheres has been demonstrated. Silliker et al. (1977) found that pork loins stored in air initially, were spoiled after four days post treatment storage at $1^{o}C$. In contrast, CO_2 treated roasts showed bacterial counts of the same magnitude as obtained when the post-treatment storage was initiated. Partnann (1980) stored broilers in 100% CO_2 and 80% CO_2, 20% N_2 for four weeks at $1^{o}C$, followed by five days storage at $4^{o}C$ in air. Those samples stored in 100% CO_2 were of a superior quality at the end of the post treatment storage in air. Spahl et al. (1981) also found the inhibition of microbial growth on pork chops in CO_2 containing atmospheres was carried over to the re-wrap environment. The possible cause of this may be either the retention of CO_2 in microbial tissues and fluids by direct binding to proteins, or solubilization of CO_2, or the result of a new lag phase induced by a change in the environment or a combination of all three (Woolfe, 1980; Silliker et al., 1977).

1.2.3.3.5. The effect of MAP and vacuum packing on the shelf-life of raw, cured and fermented meats.

The shelf-life of raw meats stored in 100% CO_2 is greater than under vacuum, which is greater than in N_2, which is greater than in air (Spahl et al., 1981; Erichsen and Molin, 1981; Hess et al., 1980). The situation is more complex with processed meats as additional factors may also become inhibitory, for example water activity (Aw), salt concentration and pH. Egan et al. (1980) reported that a total count of 10^8 organisms/g on vacuum packed sliced luncheon meats may not mean the product is spoiled and thereby at the end of its shelf-life. The rate of spoilage depends on the exact nature of the product under examination, the nature of the initial microflora, the conditions of storage and the tasters expectations. Brochothrix thermosphactum caused spoilage in luncheon meats more rapidly than lactic acid bacteria, due to the more pungent nature (sweet, sickly and malty) of the end products of its carbohydrate metabolism (Egan et al., 1980; Stanley et al., 1981).

Kempton and Bobier (1973) also found no relationship between bacterial growth and spoilage in vacuum packed luncheon meats. There were marked differences in the initial flora of the four types of luncheon meat, but after two weeks storage at 5°C, lactic acid bacteria comprised the bulk. The predominance of lactic acid bacteria and in some cases B.thermosphacta in processed meats at the end of shelf-life corresponds to observations made by Silla and Simonsen, (1985); Shay et al. (1978); Stiles and Ng, (1979); Blickstad and Molin, (1983) and Nielsen (1983).

Several investigations on the improvement of the shelf-life of cured or fermented meat products have been undertaken and their results show the beneficial effect of low O_2 atmospheres increasing the shelf-life of cured and fermented meat products (Steinke and Foster, 1951; Allen and Foster, 1960; Miller, 1960; Alm & Molin, 1961; White and

Hobbs, 1963; Kempton and Bobier, 1973; Paradis and Stiles, 1978; Shay et al., 1978; Qvist and Mukherji, 1981; Blickstad and Molin, 1983; Nielsen, 1983; Simard et al., 1983b).

Meats that have not been cured or fermented tend to be more vulnerable to a variety of microbial growth as they have a higher pH, lower Aw and contain a lower salt concentration and no preservatives, such as nitrites or sorbates.

Only one report has been found in the literature on the effect of vacuum packaging or CO_2 storage on the shelf-life of pre-prepared foods as may occur in a catering environment. McDaniel et al., (1984) found that storage of pre-cooked beef roasts in a 100% CO_2 atmosphere was preferable to vacuum packing from a microbiological standpoint. After 14 days at 4 ^{o}C the vacuum packed samples contained 4.47×10^7/g, whereas those in the CO_2 packs contained 3.71×10^5/g.

1.2.3.4 Chilling

The objective of rapid chilling is to pass through the temperature range which supports the growth of pathogenic bacteria as quickly as possible. According to Bryan (1978) and Sheard (1983) the two most common factors that contributed to the occurrence of foodborne disease in England and Wales during the 70's were the inadequate cooling of foods and the lapse of a day or more between preparation and service (Table 1.5). These two factors emphasize the importance of proper temperature control.

Table 1.5 Factors that have been shown to contribute to outbreaks of foodborne disease in England and Wales in order of importance (adapted from Sheard. 1983).

Number	Contributing factor	Percentage*
1	Preparation too far in advance	60.6
2	Storage at ambient temperatures	39.6
3	Inadequate cooling	31.0
4	Inadequate reheating	28.7
5	Contaminated processed food (not canned)	19.1
6	Undercooking	15.4
7	Inadequate thawing	6.1
8	Cross contamination	5.9
9	Inadequate warm holding	5.7
10	Infected food handlers	5.2
11	Use of left-overs	4.8
12	Raw food consumed	4.4
13	Extra large quantities prepared	3.1
14	Contaminated canned food	4.4

*Percentage of food poisoning incidents where there is sufficient detail identified to show the factors that contributed to the incidents (n=1044).

Micro-organisms gradually die when held under conditions where they cannot grow, but this may be a slow process. If bacterial cells in their log phase of growth are cooled rapidly there is a loss of viability related to cold shock. The effect of cold shock is to kill a proportion of cells, more or less promptly and to leave damaged survivors. This phenomenon may increase the effect temperature reduction alone has on the inhibition of microbial activity. Cold shock has been demonstrated with gram positive spore formers as well as gram negative bacteria. Staphylococcus aureus resists cold shock (Farrell and Rose, 1968; Sato and Takahashi, 1968). Such damage is important to be aware of in the microbiological examination of chilled foods. Bacterial counts on selective growth media may easily be less than 10 times too low, but a normal resuscitation treatment in a good medium prior to growth in selective media should prevent this (Ingram and Mackey, 1977).

1.2.3.5 Storage

Once chilled, portioned cooked foods may be stored in a refrigerated storage area or loaded into a chilled food vending machine ready for purchase by the consumer. The temperature of storage should be between 0 and 3°C (Table 1.2). However, considerable fluctuations in temperature in refrigerators in catering establishments have been found (Longree and White, 1955; Toule and Murphy, 1978; Searle and Crozier, 1981). Therefore it cannot be assumed that catering refrigerators and CFVM's are able to maintain the strict temperature range recommended for the storage of cook-chill foods by the DHSS (1980).

It has long been realized with raw foods that it is increasingly worthwhile to strive after every degree of reduction in temperature in order to increase shelf-lives. For example, the period before the appearance of slime on chilled poultry carcasses was increased from 4 to 5.5 weeks by reducing the temperature only from 1 to 0°C (Ingram, 1951).

Few similar studies with cooked foods have been reported in the literature. Bacterial counts in vacuum packed cured meats remained unchanged for 30 to 40 days longer at 1.1°C than at 7.2°C (Allen and Foster, 1960). Toule and Murphy (1978) studied the flora of cooked chicken stored at a constant 4°C and a variable 4°C (ranged between 2 - 13°C) for 10 days. At a constant 4°C the number of genera isolated were restricted and the total numbers of bacteria were tenfold lower than at the variable temperature. In contrast, Zallen et al (1975) found no difference in total plate counts of cooked beef loaves chilled and stored for 9 days at either 0 or 5.5°C. This result may have been due to the absence of micro-organisms in the cooked beef loaf capable of growth at either 0 or 5°C.

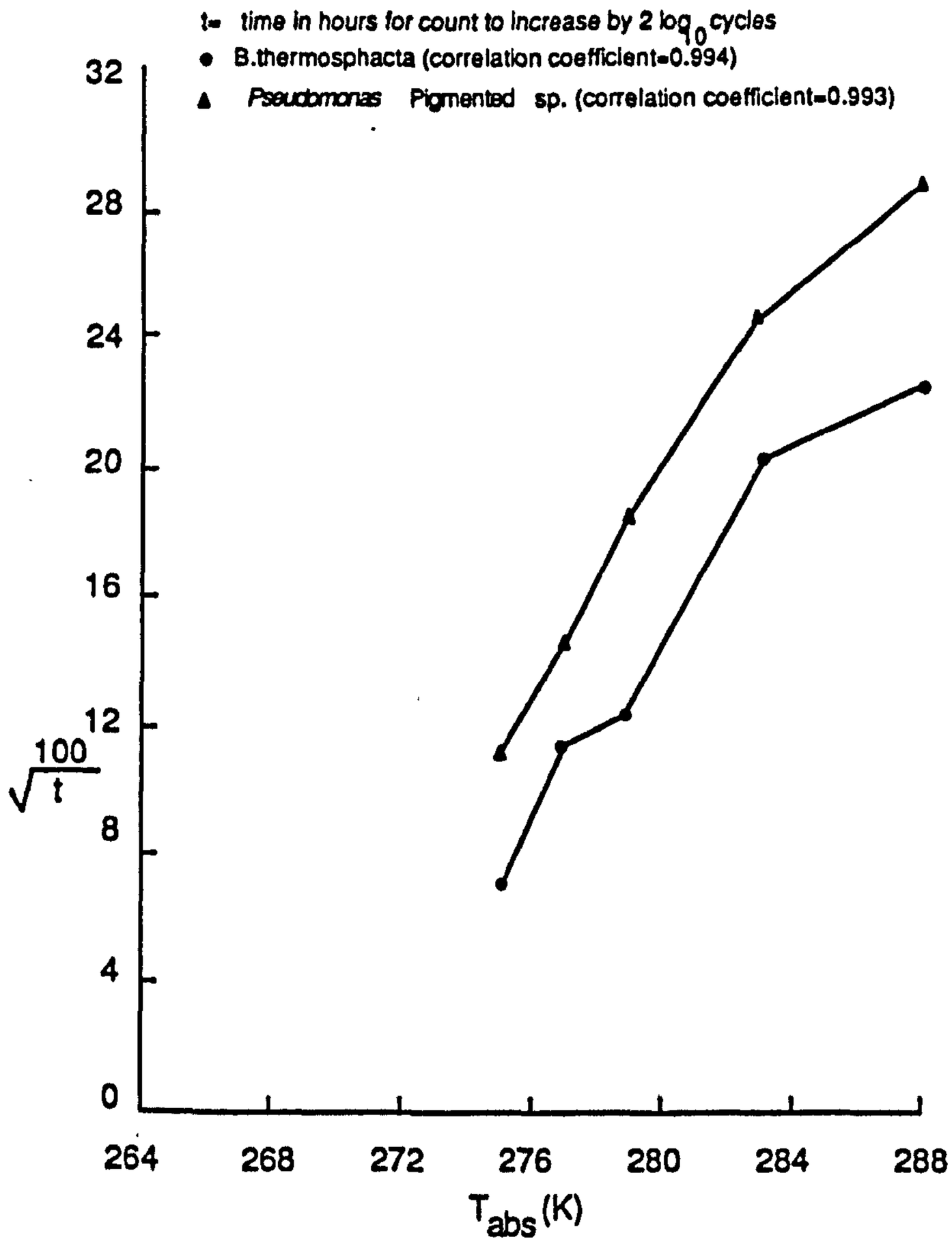
Ratkowsky et al., (1982) demonstrated that at temperatures between the minimum and optimum temperatures for

growth, the growth rate of a micro-organism is a function of temperature. In this relationship the square root of the bacterial growth rate (r) is related to storage temperature in K (T):

$$\sqrt{r} = b(T - T_o)$$

where b is the regression coefficient (slope) and T_o is a hypothetical temperature of no metabolic significance but an intrinsic property of the organism being studied. Figure 1.2 shows the straight lines obtained (correlation coefficient = 0.99) for growth of Brochothrix thermosphacta and a pigmented pseudomonas (Campbell-Platt, 1985).

Figure 1.2. Square root plot for a mixture of *Brochothrix thermosphacta* and a pigmented *Pseudomonas* sp. (Campbell-Platt, 1985)



This formula has been applied by Smith (1985), to determine the length of time raw meat may be held above the minimum temperature for growth, without an increase in the number of any Salmonellae present (assuming initial numbers of bacteria are known). To use the formula as a predictive equation would depend on precise knowledge of the initial numbers of Salmonellae or other organisms of interest. Such information is unlikely to be available in time to set the appropriate time limit.

Bacteria may be classified according to their optimum and or minimum temperatures for growth. The important groups with regard to chilled storage are psychrophiles and psychrotrophs (mesophiles may assume importance under abusive chilled storage conditions). Psychrophiles are bacteria that grow well at $0^{o}C$ within two weeks and have a maximum growth temperature below $35^{o}C$ (Ingraham and Stokes, 1959). Psychrotrophic bacteria are able to grow at $5^{o}C$ and below, without any regard of their optimum temperatures for growth (Eddy, 1960). Psychrophilic bacteria are mostly gram negative non spore forming rods; most strains belong to the genus Pseudomonas and the remainder to the genera Moraxella Acinetobacter, Alteromonas, Flavobacterium, and Alcaligenes. Gram positive psychrotrophs include bacteria belonging to Lactobacillaceae, Micrococcaceae, Brochothrix Thermosphacta, and the slower growing Clostridium and Bacillus (Campbell-Platt, 1985).

Yeasts belonging to Candida, Torulopsis, Cryptococcus, Rhodotorula, and moulds belonging to Penicillium, Cladosporium, Tricotherium and Aspergillus also grow in chilled foods (Campbell-Platt, 1985). The yeasts and moulds usually grow more slowly than the bacteria.

The risk of food poisoning from a CCV system is partly dependent on the operating temperatures within the CFVM. The minimum temperature for growth of mesophiles is between 5 - $10^{o}C$ and so, as temperatures are reduced, the growth of mesophiles is diminished. Further, a temperature which

prevents mesophilic bacteria from growing does not merely hold them static, but gradually kills them (Ingram, 1951). This is important for public health reasons because most human pathogens are mesophilic, while the psychrophilic species, although they cause food spoilage, are comparatively innocuous with respect to human health. Therefore, if chill conditions are maintained, the low temperatures naturally select for the growth of psychrotrophic and psychrophilic organisms and mesophilic pathogens are unable to grow. Clostridium botulinum type E, Listeriae and Yersinia enterocolitica are psychrotrophs (Table 1.5) that have been associated with food poisoning incidents, which indicates that not all micro-organisms that cause food poisoning are mesophiles. However, the number of incidents of food poisoning from these organisms is small relative to those caused by Salmonellae, Clostridium perfringens and Staphylococcus aureus, which are mesophiles. Any foodservice system which relies on chilled storage of cooked foods must therefore take account of these findings. However, because of the relative paucity of data on the microbiological contamination of cooked chilled foods and the unique nature of the CCV system, this field of study obviously requires much work and forms the basis of a proportion of the present study.

Examples of the minimum temperature for growth of common food spoilage and food poisoning organisms are shown in Table 1.6.

Table 1.6. The minimum temperature for growth of several pathogenic bacteria.

Organism	Temperature (°C)	Substrate	Reference
Bacillus cereus	4	Nutrient agar	Bonde, 1981
	8	Vacuum packed bologna	Nielsen & Zeuthen, 1984
Brochothrix thermosphacta	.8		Dainty & Mabb, 1971
	0	Fresh meat	Egan et al., 1979
Clostridium botulinum			
type E	3.3	Sterile meat stew	Schmidt et al., 1961
type A	10	Meat	Tanner et al., 1940
type B	10	Vegetables	Tanner et al., 1940
Non proteolytic:			
type B	3.3	Cooked meat medium	Eklund et al, 1967
Clostridium perfringens	15	Hartleys digest broth	Roberts & Hobbs, 1968
	5		Rey et al., 1975
type F	18.3	Beef cubes in gravy	Hall & Angelotti, 1965
Escherichia coli	7.2	Trypticase soy	Elliott, 1963
Listeriae	4		Dainty & Mabb, 1971
Staphylococcus aureus	6.7	Sterile custard Chicken a la King	Angelotti et al., 1961
	5	Bacon	Farrell & Upton 1978
	8	Vacuum packed bologna	Nielsen & Zeuthen, 1984
Salmonella typhimurium	8	Trypticase soy agar	Elliott, 1963
Salmonella heidelburg	5.5	" "	Matches & Liston, 1968
Salmonella seftenburg S.enteritidis & S. manhattan	6.7	Sterile chicken a la king	Angelotti et al., 1961
Salmonella panama	4	Buffered glucose tryptone soya peptone agar (G.T.S. agar)	Mossel et al.,1981
65 Salmonellae species	7	" " " " " "	
9 Salmonellae serotypes	10	Beef (not sterile)	Mackey et al 1980
Streptobacteria	4 - 8		Reuter, 1981

Table 1.6 (continued)

Organism	Temperature (^{o}C)	Substrate	Reference
Atypical streptobacteria	2 -4		Reuter, 1981
Yersinia enterocolitica	4	G.T.S.agar	Mossel et al 1981
	2	Vacuum packed bologna	Nielsen & Zeuthen, 1984

1.2.3.5.1 Factors affecting the minimum temperature for growth of micro-organisms

Many factors influence the minimum temperature for growth of micro-organisms, including the concentration and quality of nutrients in the substrate (i.e. the food), the hydrogen concentration, water activity, presence of inhibitors, microbial competition, length of storage, gaseous atmosphere and the size of the initial inoculum.

The minimum temperature for growth is lower if suitable nutrients are available in the substrate (Ingram and Mackey, 1976). Schmidt et al (1961) demonstrated this with Clostridium botulinum type E, which grew at 3.3^{o}C in beef stew, but would not grow at temperatures below 7.8^{o}C in peptone water. Most cooked chilled foods contain a wide range of nutrients, which allows them to support the growth of many micro-organisms.

Chilled cooked foods are high moisture foods with a Aw greater than 0.95 and therefore support the growth of a wide range of spoilage and of pathogenic bacteria.

The minimum temperature for growth of some micro-organisms is affected by the concentration of CO_2 in the atmosphere. Wodzinski and Frazier (1961) reported that 5 and 10% CO_2 increased the minimum temperature and Aw for growth of certain bacteria.

Gill and Tan (1980) found the inhibitory effect of CO_2 on the growth of Pseudomonas fluorescens was increased with decreasing storage temperatures. Enfors and Molin (1981) also found that the inhibitory effect of CO_2 on Pseudomonas fragi was increased with decreasing temperature within the whole temperature range tested. However, Bacillus cereus behaved differently and the inhibitory effect was weakest at the optimum growth temperature and increased at higher as well as lower temperatures. These dissimilarities may be explained by a difference in CO_2 resistance by the two organisms or by different mechanisms of inhibition.

Temperatures for growth are dependent upon the effect of other inhibitory factors and any deviation from the optimum conditions automatically raises the minimum temperature for growth.

1.2.3.6 Reheating

While reheating may cause a reduction in total numbers of micro organisms, it will not rectify any damage caused by the growth of food spoilage organisms. Neither is reheating likely to inactivate heat resistant bacterial toxins present as a result of bacterial growth in a food. For example, staphylococcal enterotoxin requires temperatures in excess of 100°C for inactivation (Georgala and Hurst, 1963).

The reheating of vended cooked foods is limited to microwave ovens operated by the consumer. Microwave reheating is characterised by rapid heating for a short period of time. The effects of microwave irradiation and holding afterwards on micro organisms in foods are influenced by both intrinsic characteristics of foods, such as pH, water activity, oxidation reduction potential, nutrient content, anti microbial constituents, biological structure, chemical composition of foods and the shape or amount of the food, and by extrinsic characteristics such as temperature, humidity, frequency and intensity of radiation, length of exposure,

position of the food in the oven, as well as the characteristics of the microflora (Fung and Cunningham, 1980).

Temperatures in excess of 73°C in the geometric centre of the food may be achieved within minutes by microwave irradiation, but the occurrence of uneven heating patterns is common (Unklesbay et al. 1977; Dahl et al 1981; Bryan and Lyon 1984). Despite such uneven heating patterns Sawyer et al (1983) reported no significant differences (5% level) in aerobic plate counts of foods individually reheated by microwave or convection systems to the same end temperature.

Fruin and Guthertz (1982) assessed the destructive effect of different cookery methods, including microwave irradiation on bacteria innoculated onto meat leaf. Temperature variation within the food was greatest for those cooked in a microwave oven. However, for each bacterial strain and the total count, the destructive effect of the cooking method was not significantly different (5% level).

Several direct challenge studies of certain foodborne pathogens show that they may survive microwave irradiation during reheating, even though temperatures were reached in the geometric centre of the foods that were high enough to kill large numbers of them if they had been heated by conventional means. This was in part accounted for by the temperature variation that occurs in foods heated in microwave ovens (Bunch et al 1977; Dahl et al 1980).

It seems then that significant survival of bacterial contamination after microwave reheating of vended chilled foods could occur but would be primarily related to improper cooking, handling or storage (or all three) and therefore the present study concentrated on these more crucial issues.

1.3. A review of naturally occurring microflora in cooked chilled menu-items

The microbiological study of menu items prepared by cook chill systems may be undertaken on systems simulated in the laboratory or actual operating systems. Both types of study have been described by Snyder and Matthews (1984) in their review of the microbiological quality of menu items prepared by cook chill, cook freeze, cook hot-hold and heat serve methods. The cook chill section of their review will now be expanded to describe the composition and behaviour of the microflora of cooked foods during refrigerated storage and to emphasize the variability in results between and within investigations partly due to widely differing parameters of chill storage and, in particular, storage temperature.

Both the laboratory studies and the studies of operating systems found a wide variation in total plate counts (TPC) of menu items. This variation was found within a single sample of a menu item (Bunch et al 1976), between samples produced simultaneously (Dahl et al 1980) or between samples produced at different times by the same system (Nicholanco and Matthews, 1978; Cremer and Chipley, 1977, 1979 & 1980). The composition and numbers of micro-organisms in cooked foods are determined by:

a) the microflora of the raw food;
b) the processing parameters; and
c) the numbers and types of post processing contaminants.

The lack of information in the literature on the composition of the micro flora after cooking and the different combination of times and temperatures employed by different investigators make it difficult to compare results between studies. Details of the reviewed studies, including menu items refrigerated conditions and major findings are given in Table 1.7.

Table 1.7. Studies undertaken to examine the naturally occuring microflora of menu items during the process stages of cook chill foodservice systems.

Studies of operating systems

Reference	Menu item	Chilled storage conditions	Analyses	Results
Rowley et al., 1972	Bakery items, meat & entree items,salad items	Rapid chilling to 7.2 °C in 2 hours. Storage at <4.4 °C for < 96 hours.	TPC Sensory analysis Consumer tests	After cooking; TPC most samples <200/g After 9 days storage; meats increased to 1.5 - 1.6 x 10^5/g. lyonnaise potatoes >10^6/g
Bryan & McKinley, 1974	Roast turkey	Cooled at room temperature for 1 - 3 hours. Stored whole at 7.2 °C for 18 hours.	*Cl. perfringens* *Staphylococci* Salmonellae	After cooking; all tests negative
Cremer & Chipley, 1977	Spaghetti & Chilli	Chilled in a mechanically stirred chilled tank at -12.2 °C for 1.2 hours. Stored between -1.1 - 16.6°C for 100 -130 hours	TPC Clostridia Yeasts & moulds Staphylococci Coliforms	After cooking; TPC spaghetti 2.1 x 10^3/g chilli 1.1 x 10^3/g After storage; TPC spaghetti 5.7 x 10^3/g chilli 2.1 x 10^4/g Clostridia numbers increased during storage from .34 to 2.04 x10^3/g in spaghetti.
Nicholanco & Matthew, 1978	Beef stew	Chilled & stored at 5.5 - 10 °C for 22 hours	TPC Total coliforms Sensory analysis Vitamin retention	After cooking; TPC 4.6 - 8.1 x 10^4/g After storage; TPC 7.5 - 18.0 x 10^4/g
Avens et al., 1978	11 menu items; entrees, vegetables & desserts		TPC Coliforms Escherichia Coli Coagulase positive Staphylococci	No system was significantly different in the microbiological quality of the food delivered.
Cremer & Chipley, 1979	Meat loaves	Chilled & stored for 25 - 80 hours at 4 - 18 °C	TPC Yeasts &moulds Staphylococci Coliforms Clostridia Sensory	After cooking; TPC; 2.3 - 3.7 x 10^3/g Staphylocci;1 - 3 x 10^2/g Coliforms; 2 - 4 x 10^2/g Clostridia; 6 -12 x 10^2/g
Cremer & Chipley, 1980	Roast beef	Chilled & stored for 45 hours at 1.7 - 6.7 °C (at room temperature for 3.5 hours)	TPC Yeasts &moulds Staphylococci Coliforms Clostridia Sensory	After cooking; TPC; 1.2 x 10^3/g Staphylocci;10/g Coliforms; - Clostridia; 2.7 x 10^2/g Yeast & moulds; 40/g
Cremer et al., 1985	Chicken & noodles	Packed in plastic casings, chilled in a water bath at 8.7+3°C for 2 hrs. Stored at 0.2°C for 3-31 days.	TPC Coliforms Staphylococci Anaerobic spore count	After cooking; All counts <3.0 x 10^2/g After storage; All counts <3.0 x 10^2/g
Matthews & Marth, 1980	Beef loaf Potatoes	Chilled & stored for 24 hours at 7 °C	TPC	After cooking; TPC; 10^1 x 10^4/g After storage; Potatoes; 1.5 x 10^3 - 4.7 x 10^6/g Beef loaf; <3 x 10^2 - 6.8 x 10^5/g
Rini et al., 1981	Beef loaf	Chilled & stored at 1 ± 1 oC for 24 ± 1 hours.	TPC Yeasts &moulds Coliforms Staphylococci Clostridia	After cooking;coliforms, yeasts & moulds and staphylococci all negative. TPC; 7.8 x 10^1/g Clostridia; 1.7 x 10^1/g After storage; TPC; 1.3 x 10^2/g Clostridia; 3.3 x 10^1/g

Studies of simulated systems

Reference	Menu Item	Chilled storage conditions	Analyses	Results
Patterson & Gibbs, 1975	Roast chicken	Chilled at 1 ^{o}C for 1 hour. Stored at 1 - 3 ^{o}C or 16 ^{o}C for 7 days.	TPC	After cooking;TPC of breast skin <.3 - 14 x 10^3/g After storage;TPC of breast skin at 1 - 3 oC;.9 - 4.5 x 10^3/g at 16 oC;<3x10^2 - 2.4x10^5/g.
Tuomi et al., 1974	Ground beef gravy	Chilled in a water bath at <10 ^{o}C for 1 hour. Stored at 4 ^{o}C for 16 hours and a further 5 hours at 5.5 ^{o}C.	TPC *Cl. perfringens* Coagulase positive *staphylococci.*	After cooking; TPC; 5.0 x 10^1/g After storage; TPC; 4.4 x 10^2/g *Cl.perfringens* negative *Staphylococcus aureus* positive in some samples.
Zallen et al, 1975	Meat loaf	Chilled and stored at either 0 or 5.5 ^{o}C for 9 days.	TPC Cooking losses TBA test Sensory	After cooking; all loaves but 1 TPC; < 1.0 x 10^2/g After storage; all loaves but 2 TPC; <1.0 x 10^2/g
Bunch et al, 1976	Beef soy loaf	Chilled and stored at 5.5 ± 3 ^{o}C for 24, 48 or 72 hours.	TPC Consumer evaluation	After cooking; TPC corner of loaf; 2.1-4.2x10^3/g centre of loaf; 5 - 7 x 10^4/g After 24 hours storage; TPC centre of loaf;1.3-1.5x10^5/g
Toule & Murphy, 1978	Roast chicken	Chilled & stored at either (1) 4 ^{o}C or (2) 2 - 13 ^{o}C for 10 days.	TPC McConkey agar Mannitol salt agar Trypticase soy agar Identification of isolates	After cooking; TPC; .1 - 1.0 x 10^3/g After storage; TPC; (1) 4.2 - 10.6 x 10^6/g (2) 2.1 - 3.9 x 10^7/g
Shelton & Ainsworth, 1981	Brussels sprouts, Minced beef in stock	Storage 8 days (a)	TPC Coliforms Vitamin retention	After cooking;TPC sprouts;4.8 x 10^3/g meat; 6.3 x 10^4/g After storage;TPC sprouts; 7.8 x 10^3/g meat; 5 x 10^5/g after 6 days

(a) chilling times and temperatures not given.

1.3.1 Studies of operating cook-chill systems

A report on the use of central food production systems for military feeding purposes in America recommended the use of cook chill following extensive microbiological, sensory and consumer tests of menu items (Rowley et al 1972). Representative menu items were microbiologically examined during chilled storage at 4.4°C for up to nine days. Most cooked meat and vegetable items had low initial total plate counts, which were either static or decreased during chilled storage, with the exception of roast beef, corned beef and O'Brian potatoes. Some partially cooked or baked vegetable items, e.g. lyonnaise potatoes, had relatively high initial counts which increased during refrigerated storage to greater than 10^6 organisms/g of sample. After initial cooking, soups and chowders had low TPC and numbers of micro organisms did not increase on chilled storage, with one exception: TPC of cream of potato soup increased from 2.0×10^2 to 1.8×10^5 after 7 days storage. The authors concluded that cooked foods showing high TPC after chilled storage, such as the potato soup, are not necessarily considered hazardous because of their actual count. However, total plate counts in excess of 10^6 organisms/g suggest improper handling and a potential food poisoning hazard (Rowley et al., 1972).

The production of spaghetti and chilli in an American school food service system was studied by Cremer and Chipley (1977). After cooking, the products were rapidly cooled in a mechanically stirred chill tank. The total storage time was equal to 24 hours. During the 24 hour storage, a five to tenfold increase occurred, which was followed by a five to twenty fold decrease after reheating. Higher values were observed for *Clostridia* than for yeasts and moulds, *Staphylococci* and *Coliforms*. During storage the numbers of *Clostridia* increased which represents a potential health hazard. Variable results were found among replications of sampling.

Nicholanco and Matthew (1976) investigated the quality of beef stew in an American hospital chill foodservice system. For the first nine hours of chilled storage the temperature of the food remained above 7.2°C. The TPC was lowest after the initial cooking process (from 4.6 to 8.1 x 10^4/g) and after reheating (0.8 to 10.0 x 10^4/g). After chilled storage the count had risen to between 7.5 and 18.0 x 10^4/g. All Coliform counts were less than 10/g and remained static. A large variation in bacterial counts was found between three separate trials.

Avens et al (1978) compared four American school food preparation and delivery systems: conventional on site preparation and service; central kitchen preparation and hot bulk transport to outlets; central kitchen preparation and chilled transport and frozen pre-portioned meals reheated in schools. Eleven menu items were examined. Analysis of variance of the TPC showed differences between different foodservice systems not to be statistically significant; differences between schools and sampling points were statistically significant. They concluded that the desirability of different systems may be based on factors other than microbiological food safety.

The preparation and service of meat loaf in a cook chill foodservice system was investigated by Cremer and Chipley (1979). TPC generally increased during chilled storage, during which time samples were found to contain Bacillus species, Clostridium sporagenes, Clostridium perfringens, Staphylococcus aureus and Staphylococcus epidermidis. Variable results were obtained among replications of sampling.

The production of roast beef in a hospital cook chill system was investigated by Cremer and Chipley (1980). After initial cooking the food was stored for 45 hours, within which time it was held for 3.5 hours at room temperature. After four hours of chilled storage the mean temperature of the meat was 27.7°C and for the rest of the storage period,

the temperature rarely reached 7°C. This was attributed to inadequate refrigeration equipment and poor air circulation, due to badly positioned products within the chilled storage area. After initial cooking and before reheating, the TPC increased three to elevenfold. This was attributed to long storage times at temperatures conducive to microbial growth and the introduction of contaminants during handling. Even after reheating samples were found to contain Bacillus species, Clostridium sporagenes, Clostridium perfringens, Staphylococcus epidermidis and Staphylococcus aureus. Variable results were obtained among replications of sampling. The need for controlled cooling rates and prevention of contamination of food by food handlers and equipment was emphasized.

Rini et al (1981) examined the microbiological quality of beef loaves prepared according to four different foodservice systems, one of which was a cook chill system. The TPC were reduced to low levels, after baking the loaves to an internal temperature of 96°C. Increases in TPC and clostridial counts were observed as meat was held chilled for 24 hours. Two areas of concern were emphasized; the survival of sporeforming bacteria and the cooked loaves exposure to external sources of contamination.

1.3.2 Systems simulated in the laboratory

Patterson and Gibbs (1973) examined the micro flora of cooked chicken carcasses stored for 7 days at 1 - 3°C and at 16°C for 10 days. During cooking all parts of the carcasses reached and maintained 85°C for at least 50 minutes and the resulting flora consisted largely of sporeforming bacteria. Storage at 3°C for up to 7 days resulted in only a slight increase in microbial numbers and non spore forming bacteria were not detected. After 21 days at 3°C no Bacillus or Clostridium viable cells or spores could be detected. Storage at 16°C for 3 days markedly increased the numbers of non spore forming organisms, though

no off odours were detected until at least ten days. There was clearly little post processing contamination of the chickens and rapid chilling to 3°C prevented substantial growth of heat resistant spore forming organisms.

Tuomi et al (1974) simulated the production of ground beef gravy as may occur in a hospital cook chill system. The gravy was packed hot into plastic bags, cooled in chilled water for one hour and refrigerated for 21 hours. After cooking, coagulase positive Staphylococci were found in some samples, but the numbers did not change markedly during the holding or heat treatments. No Clostridium perfringens were found.

Zallen et al (1975) compared the microbiological quality of samples of beef loaves, prepared by different methods, including cook chill. Only two of the samples of loaves under chilled storage had total plate counts greater than 100/g and approximately half of the samples had counts of zero. There was no progressive microbial growth over the nine day storage period or observable effect of differences in microbial growth at different storage temperatures (0 and 5.5°C).

Toole and Murphy (1978) chilled and stored cooked chicken in a catering refrigerator at an average temperature of 4°C (range 2 to 13°C) and at a constant 4°C. Storage at the variable 4°C resulted in a tenfold increase in numbers of micro organisms as compared with storage at the constant 4°C. Many of the bacteria from the spoiled chickens were also isolated from the kitchen environment (Pseudomonas and Aeromonas).

Bobeng and David (1978) developed and assessed Hazard Analysis Critical Control Point Models (H.A.C.C.P.) for the quality control of beef loaf production in 3 foodservice systems: conventional, cook freeze and cook chill. They found baking the loaves to at least 60°C was sufficient to destroy almost all of the bacteria in the uncooked product.

In the cook chill system there was no bacterial growth during subsequent chilled storage. Five hours were required to reduce the internal temperature of beef loaves to 7.2°C and therefore in the event of any post baking contamination, control during chilling would have been questionable.

Shelton and Ainsworth (1981) examined the microbiological quality of brussels sprouts and minced beef in stock prepared by cook freeze and cook chill methods. Samples of the cook chill product were taken for analysis after cooking, after rapid chilling and on days one to eight of chilled storage. A reduction in TPC was observed on initial chilled storage, but continued to increase throughout the rest of the storage period, until they became too numerous to count in the minced beef stored chilled for longer than eight days.

Sawyer et al (1983) found slight increases in the total plate counts of potatoes (from 5.5×10^2 to 2.4×10^3) and peas in a simulated cook chill system after chilling at 7°C for 24 hours. Under similar conditions the total plate counts of beef loaf decreased from 3.9×10^4 to 7.6×10^3).

Dahl et al (1980) evaluated the microbiological quality of beef loaf, potatoes and green beans as prepared by a hospital food cook chill system. During chilled storage of beef loaf (7°C for 24 hours) the TPC dropped but the range in numbers was wide. Under similar conditions, the total plate counts of potatoes increased; but again wide variations were found.

1.4. Sensory quality

The sensory quality of a food may be examined from two points of view: the sensory or organoleptic characteristics of a food, which may be evaluated objectively by "trained experts" and the subjective evaluation by consumers of the

acceptability of a product or of product preferences. These two areas may have no bearing or relationship to each other; for example, two similar products differing in their sensory characteristics may be equal in terms of consumer preference.

1.4.1 Chemical and physical changes

When cooked menu items are subjected to storage in a vending machine, chemical and physical reactions take place causing the sensory characteristics of a food to alter. Some of these changes and their cause are listed in Table 1.8.

Table 1.8 Degradative changes occurring during the chilled storage of cooked foods.

Sensory changes	Cause
Loss of colour	Pigment changes
Surface drying	Low relative humidity
Surface condensation causing sogginess or stickiness in bakery products	High relative humidity
Separation of starch based sauces Staling of bread	Starch retrogradation
Development of off odours or flavours	Proteolytic or lipolytic activity of micro-organisms
Development of rancid odours or flavours	Oxidation of fats

Where the microbiological quality is assured for several days, other quality factors come into play. The sensory changes occurring in cooked food on chilled storage may then be the limiting factor on shelf life.

There are few reports in the literature identifying or quantifying the sensory changes in cooked stored foods.

Certain microbiological studies relate the time taken to reach off odour or flavour to microbiological data (Griffiths, 1985) and commercially a test for off odour production is probably the most widely used criterion of spoilage (Pooni and Mead, 1984). However, this off odour or flavour may be preceeded by other sensory changes which influence consumer acceptability. The occurrence of rancidity in cooked meats within a few hours of cooking, with the development of a characteristic warmed over flavour (WOF) is well documented (Pearson et al, 1977), but it is unclear how this affects consumer acceptability. Conditions used to delay bacterial spoilage usually retard the development of rancidity; vacuum packing and anaerobic gas packing reduce the oxygen content and microbiological spoilage occurs before the development of rancidity (Enser, 1985).

1.5. Purpose and scope of the present study

The purpose of this study is to investigate how the unique operational aspects of a cook chill vend system (length of storage time and storage temperature within the CFVM and also type of packaging), influence the sensory and microbiological quality of menu items. A mathematical model will demonstrate how a fully integrated analysis, based on these operational considerations, may be developed. The aims of the model development are:

a) to determine whether consumer preferences are influenced by variations in vended storage conditions and if so in what way,

b) to establish the relationship between the sensory characteristics of a product and consumer preferences,

c) to predict consumer preferences given a set of storage conditions, assuming other operational conditions are standardized

d) to examine differences in preference between individual consumers in the population and to develop separate models for consumers with differing preferences

A background to the food vending industry was gained by a nation wide survey and is described in Chapter 3. A time temperature survey of the operating conditions of CFVM's was undertaken to establish the potential for growth of food poisoning organisms (Chapter 4). The microbiological quality of cook chill vend menu items is considered further in Chapter 5, where the effect of time and temperature of storage and type of packaging on the micro-flora of cooked foods is examined. The effect of these variables on sensory quality is established in Chapters 6 and 7. The penultimate Chapter (Chapter 8) describes the development of a mathematical model from the sensory data and experimental variables.

CHAPTER 2

MATERIALS AND METHODS

The methods which were used routinely throughout the work described in this thesis, or which occur in more than one chapter are described below.

2.1. Preparation of chicken a la king

Preparation was carried by means of good hygienic practice of regular catering methods. The quantities of ingredients are shown in Table 2.1. The chickens were obtained frozen, stored at -20°C and then were defrosted overnight at room temperature (15 - 20°C). The giblets were removed and the chickens were washed under cold running water and placed in a Groen steam jacketed kettle with the whole peeled onions and carrots and covered with water. This mixture was brought to the boil and skimmed to remove any scum that had formed. The bay leaves, peppercorns and cloves were added and the chickens were simmered for 75 minutes. The chickens were drained from the cooking liquor and placed immediately on trays in Foster blast chiller to cool for between 30 minutes and one hour.

A chicken veloute was prepared by melting the butter (Table 2.1; i) in a heavy based pan over a medium gas flame on a Benham six gas burner hob. The flour was stirred in with a wooden spatula and cooked until it took on a sandy appearance (3 to 5 minutes). The pan was removed from the heat and the chicken cooking liquor was stirred in. The pan was replaced onto the gas burner and the sauce was stirred until it had thickened and come to the boil. The sauce was simmered for between 3 to 5 minutes and then removed from the heat and covered with greased greaseproof paper to prevent a skin forming.

The chicken meat was removed by hand from the partly cooled chicken carcasses (plastic gloves were worn). Any

bones or skin were discarded. The meat was chopped by hand into a 2 cm dice.

The butter (Table 2.1; ii) was melted in heavy based pan over a medium gas flame. The defrosted frozen peas (thawed for between 1 and 2 hours at room temperature) and diced pimento were fried in the butter until heated through. The chopped meat was added to the pea and pimento mix and stirred with a wooden spatula for 3 to 5 minutes. The masala was added next and stirred into the mix until it had nearly all evaporated (3 to 5 minutes). The chicken veloute was stirred in and the mix was brought to the boil and simmered for 5 minutes, during which time the salt was added. The finished chicken a la king was poured into 9 cm deep trays (the depth of the chicken a la king did not exceed 5 cm) and covered with greaseproof paper. The trays were placed into a Foster blast chiller for 90 minutes.

Table 2.1 Chicken a la king ingredients

	Quantity
Frozen chickens (1.5 Kg)	3
Carrots	400g
Onions	400g
Bay leaves	3
Peppercorns	6
Cloves	6
Water	2L
Veloute:	
Flour	120g
Butter (i)	120g
Cooking liquor	1.5L
Sauce:	
Butter (ii)	60g
Frozen peas	180g
Canned pimento	110g
Masala	150mls
Salt	20g

2.2. Preparation of deep fried chicken drumstick

Chicken drumsticks were obtained frozen, stored at -20°C and then defrosted overnight in a Foster refrigerator at 0 to 5°C. They were washed under cold running water, trimmed of loose skin and patted dry with paper towelling. The oil was heated to 155 + 5°C in a Benham deep fryer (25 L oil capacity). Thirty drumsticks were fried for 15 minutes in two wire baskets. The drumsticks were drained from the oil, shaken in the baskets to remove excess oil and tipped onto trays, which were covered with absorbent paper towelling. The trays of drumsticks were placed in a Foster blast chiller for 90 minutes.

The conditions of frying were controlled by standardizing the rate of adding fresh oil to the used oil in the fryer. Fresh oil (vegetable cooking oil supplied by KTC, Wednesbury,UK) was used to cook chicken drumsticks in the pilot experiments. In the later experiments 80% used oil and 20% fresh oil were used for each frying session. After which, the oil was filtered and the fryer was cleaned out.

2.3. Packaging

The three packaging treatments included, cling wrap, vacuum packing and modified atmosphere packaging (MAP). The cling wrap film was supplied by Perfawrap, High Wycombe, UK and had the following rates of transmission; water vapour: 90g/m^2/24 hours, O_2: 5400ml/m^2/24 hours, CO_2:35000ml/m^2/24 hours (figures were suplied by Perfawrap).

Amilon bags were used for the MAP and vacuum packing and were supplied by Otto Nielsen, St Albans, UK (moisture vapour transmission rate at 4°C, 100% R.H.; 0.13g/24 H/m^2 and O_2 transmission rate at 4°C, 21% RH; 2.5 ml/24 H/m2 (the figures were supplied by Otto Nielsen)). The MAP and vacuum

packing were undertaken on a Multivac A300. The gas composition used for MAP was 70% CO_2 and 30% N_2.

Fifty gram portions of chicken a la king or individual drumsticks were placed into polypropylene containers (12 x 9 x 4.5 cm) suitable for microwave reheating. The containers were either inserted into amilon bags if to be packed under modified atmosphere or were wrapped in cling film. The samples to be vacuum packed were placed directly into the amilon bags. A wide necked funnel was used to dispense the a la king into the bags, in order to keep the sealing edges of the bags clean.

2.4. Storage in a chilled food vending machine

The samples were stored in a Rowe 448 chilled food vending machine (CFVM). The operating temperature of this CFVM was monitored by a Grant miniature time temperature recorder. The length of storage depended on the particular experiment.

CHAPTER 3

A SURVEY OF THE VENDING INDUSTRY SERVING COOKED MENU ITEMS.

3.1. The survey

The purpose of the survey was to provide background information about the nature of the vending industry and the systems of chilled food handling employed. It would also establish a scenario against which the application of modifications to existing systems could be examined.

There are approximately 50 machine manufacturers and distributors and about 220 vending operators in the U.K., although few are involved with full meal vending. Most of the machine manufacturers and distributors and approximately 50% of the operators belong to the Automatic Vending Association of Britain. Nationally, there are 50,000 vending machines and 250,000 confectionery and beverage machines (Mintel,1981).

3.2. Methods

Questionnaires were designed to gather information about the nature of an organizations involvement with full meal vending, the extent of full meal vending and a description of the full meal vending system in operation (products, method of production, packaging, product storage times within vending machines, machine models and disadvantages of the system). A copy of the questionnaire is shown in Appendix 1.

An attempt was made to distribute the questionnaire to all known organizations involved with full meal vending. Names of organizations were obtained from the catering and vending press, the Automatic Vending Association of Britain handbook (AVAB,1983) and also through personal communication. Sixty questionnaires were distributed (Table 3.1).

Personal interviews were also undertaken, in order to clarify and support the questionnaires and provide background anecdotal information. Sixteen personal interviews were undertaken with the three largest distributors of chilled food vending machines (CFVM) and other organizations representative of the different areas of full meal vending (FMV) and of the FMV systems encountered in the questionnaires (Table 3.2). Criteria for selection of interviewees was based on the employment of a FMV system and also geographical location. All respondents to the questionnaire who employed FMV and who were within one days travel of Dorset were approached for an interview. Interviews were informal, but their structure was similar to that of the questionnaire.

Table 3.1 Recipients of questionnaire

Groups	Sector	Total number sent to each sector	Replies received
1.	Vending operators	14	ARA Vending Comovend Intex ltd. Park Warren Thames Valley Vending
2.	Vending operators/ contract caterers	10	Catering by County Consultant Caterers Lasts Auto Catering Sutcliffe Vending Vending and Catering Services Vending and Catering Supplies Vendustrial Mercantile Catering Services
3.	Vending food suppliers	1	Grand Foods
4.	Manufacturers/ Distributors of machines	6	Autobar Polyvend Roboserve (also an operator) Sankey Vending Limited Wittenborg
5.	Vending division of a catering company	3	Grand Met Vending (now Compass vending) Vendability Light Oaks Vending
6.1.	Industrial caterers operating a vending service	16	American Express Abbey Life British Telecom International British Telecom Inland Commonwealth Smelting Courtaulds Acetate Davenports Brewery Kelloggs Raychem Reckitt & Coleman Toiletries Division Smiths Industries Wyeth Laboratories

Groups	Sector	Total number sent to each sector	Replies received
6.2	Hotels	4	Central Hotel, Glasgow Gleneagles Gatwick Hilton
6.3.	Hospitals	5	Hammersmith Health Authority Royal National Orthopaedic Hospital John Radcliffe Hospital, Oxford New East Hospital, Surrey
6.4	Leisure and Social Centres	4	Auchenharvie Swimming Pool Bracknell Sports Centre
6.5	Colleges & Education establishments	3	Leeds education department
6.6	Railways	1	
Total number sent:		62	**Total number of replies:** 42

Table 3.2 Types of organization interviewed

Vending operators:

Units 1 - 4*
ARA vending
Comovend
Intex
Roboserve; Smiths Industries

Industrial caterers operating there own vending service:

Units 5 - 8*
British Telecom International
British Telecom Inland
Courtaulds Acetate
Wyeth Laboratories

Manufacturers/Distributors of machines

Units 9 - 11*
Roboserve
Sankey Vending
Wittenborg

Vending divisions of catering companies

Units 12 - 13*
Grand Met Vending
Vendability

Contract Caterers/vending operators

Units 14 - 15*
Mercantile Catering Services
Vendustrial

Hotels using vending for staff feeding

Unit 16*
A large hotel.

*: In order to maintain confidentiality, the order in which companies are listed within any one related group of similar companies, does not necessarily correspond to the unit numbers assigned within that group.

3.3. Results and discussion

A 70% response rate for the questionnaires was obtained, although only 69% of respondents served chilled foods from CFVM's. A full statistical analysis of the results of the questionnaires was not thought appropriate as the recipients involvement in full meal vending differed widely and thus their responses were not directly comparable. In addition, the sample size of organizations that were comparable was considered to be too small for significance testing. Therefore, the information in the questionnaires was collated in a characterization process and descriptive statistics are given where thought appropriate.

3.3.1. Classification of the full meal vending market in the UK.

The vending industry is complex and so for the purposes of this study the organizations involved in FMV were classified into six groups, the sixth of which had six sub groups as shown in table 3.1. Vending machine operators (Group 1) supply machines to third parties and service the machines by means of regular cleaning and refilling of machines with vending products. The main characteristic of the independent organization (groups 2, 5 and 6) when compared to vending operators is that supplying food and drink either by traditional methods or through CFVM's is a subsidiary activity of the independent organization. Many of the larger catering companies have separate divisions dealing solely with vending, for example units 12 and 13 (see table 3.2).

3.3.2. Growth and expansion in the full meal vending industry.

Results from the present survey indicate that FMV has developed more rapidly over recent years relative to other types of food and beverage vending. Of 29 companies involved

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The reason for the growth of full meal vending is primarily associated with cost cutting. It is estimated that the savings in a catering subsidy can be between 40-50% in a small site and 50 - 60% where there are a lot of customers (Anon, 1982a). However, economics is not the only advantage of vending foods: a service that is extended to 23.5 hours per day was believed to be a significant advantage (half an hour is required daily to clean and fill machines). There are also other less obvious reasons to vend foods. One example noted by the survey relates to the lease held by a leading insurance company which did not permit cooking on their London premises. Reconstitution by microwave did not legally come within this definition and so vending was an appropriate method of staff feeding.

The areas where full meal vending are expanding include: companies which are growing in size but do not want to pay for a full catering service; companies which are shrinking and can no longer afford traditional catering service; situations where work patterns are changing to include longer hours and working week ends and lastly, high technology industries such as computing where the use of machinery to automate traditional processes is common.

Potential new markets include garage forecourts and night service in hotels. In countries where vending is well developed such as the US and Japan, vending machines are a common sight on street corners and open public places. This situation is unlikely to arise in the UK because of the constraints of the British rating system.

3.3.3. Usage rates

Where chilled food vending machines are available their frequency of use depended on the approaches taken to their operation. For example, unit 16 always employed a vended food service system for staff feeding and staff received vending tokens as part of their conditions of work, thus usage was

high. In other situations, where full meal vending replaced a traditional system, numbers using in house catering facilities sometimes dropped considerably, even by as much as 80% (unit 4, unit 5). In general, usage was the same as that encountered in industrial catering situations, with one in three of the work force utilizing facilities (unit 4).

3.3.4. Methods of preparing cooked menu items for CFVM's

The number of organizations using different methods of food production systems is shown in Table 3.3.

Table 3.3 Methods of food production in full meal vending.

	Method of food production (Number of units employing each method)			
Shelf-life	Tradit-ional	Cook-chill	Bought ready prepared	Frozen
0 - 24 hours	9	-	7	-
>24 - 48 hours	5	1	3	-
>48 - 72 hours	-	-	-	-
>72 - 96 hours	-	-	1	1
>96 -120 hours	1	5	2	-
No data on shelf -life available	4	1	4	1
Total	19	7	17	2

3.3.4.1. Traditional methods of food preparation coupled with slow chilling in conventional refrigerators.

Seventy percent of the organizations interviewed who prepared their own food prepared food items by this method.

Shelf-lives were limited by nearly all the organizations concerned to less than 48 hours, largely because rapid chilling methods were not employed (Figure 3.1).

One example of this method was found at unit 4 which has a central kitchen operating for 16 hours a day and producing up to 1,000 meals (not all destined for CFVM's). The meals for the CFVM's are plated hot, chilled in a refrigerator and wrapped .This company believed that the use of a blast chiller was too big an investment, not yet warrented by their operation.

3.3.4.2. Rapid chilling by the cook chill process

This process is used by 7 of the organizations interviewed. Adhering to the DHSS Guidelines on precooked chilled foods (DHSS;1980), a product shelf life of 5 days was claimed by 6 of the 7 organizations using the cook-chill method. As an added precaution Unit 14, which produces 4,000 to 5,000 meals per day reduced the shelf-life to 4 days for all products and less for certain items, including bread items and jacket potatoes, which deteriorate more rapidly.

Unit 1 converted a traditional kitchen for staff feeding of a single factory to a central cook chill commissary which produces the menu for a complete vended service in that factory and also for chilled food vending machines in neighbouring factories.

Unit 8 employed a similar idea; a cryogenic central cook chill kitchen supplied the on-site staffed catering service and supplementary chilled food vending machines, as well as chilled food vending machines situated in a local sports centre.

Unit 13 employed a number of methods of food preparation. As they are a division of a larger catering company they were able to obtain chilled items from the

companies central cook-chill unit and also frozen items from its cook-freeze unit.

3.3.4.3. Defrosted frozen foods

Only two organizations used defrosted frozen foods in their CFVM's. Unit 7 used cook-freeze products from one of their cook-freeze commisaries to supply a complete vending food service on one of their sites. In an on site finishing kitchen the foods were rapidly defrosted, plated, wrapped and blast chilled prior to loading the chilled food vending machines.

Unit 13 offered a range of vended foods. Certain of their fork snacks were produced in a central cook freeze commisary and thawed and plated up in Unit 13's end kitchen. Other products were prepared in the end kitchen.

3.3.4.4. Ready prepared cooked menu items

Seventeen of the organizations interviewed purchased ready prepared foods that simply required reheating by the consumer if necessary. The range of these products was limited to pies, pasties, pizzas, hamburgers and hotdogs. The shelf-life would be determined by the manufacturer and controlled by means of date stamping.

3.3.5. The shelf life of vended cooked foods

The product shelf-life was determined by the method of preparation; cook-chill products were associated with a longer claimed shelf-life than the traditionally prepared items (Table 3.3). Not surprisingly, storage time in the CFVM was less than the claimed storage life. Only four organizations stored products for longer than 24 hours in the CFVM and the maximum vended storage time did not exceed 3

days. Various reasons were given for this limited storage time, including; the absence of a blast chiller, therefore non-compliance with the DHSS recommendations; a deterioration in quality, particularly appearance and texture even when a blast chiller was used; and customer resistance (recognizing products that had been in the machine the previous day). Several operators who employed traditional methods of food preparation were unaware of the shelf life extensions available through cook chill and the principles by which it is achieved.

3.3.6. Wastage

The high perishability of vended products inevitably leads to high levels of wastage. Quoted figures for this ranged from none to 40% and averaged 8.0% (standard deviation; 9.7%). Seventeen organizations claimed wastage rates to be below 15 %. High or low wastage rates did not appear to be associated with a particular method of food production or type of organization. Reasons for a particular wastage rate were therefore dependent on other factors. For example, little waste was found in hotels using vending for staff feeding, meals were not paid for by staff and therefore meal uptake was high and it was easier for the management to balance supply and demand. Most wastage was found in the opposite type of situation, for example, where demand fluctuated from day to day and could not be predicted. Unit 15 quoted high wastage rates as the reason why they were not serving plated meals. Unit 14 believed their four day shelf life reduced wastage but even so had a built-in cost factor to account for it. They also used a computer model to predict demand based on previous ordering patterns.

3.3.7 Portioning and packaging

The range of packaging used for vended food is at present fairly limited. Of the 19 organizations who supplied

main meals through CFVM's, nine favoured serving food on crockery, while four preferred the use of disposables (6 had no preference). Many of the latter are designed to fit inside the drums of CFVM's. These disposables must be able to withstand extremes of temperature from well below freezing to those obtained in a microwave oven, must be attractive, water and grease resistant and be rigid enough to provide a cutting surface. It is not surprising that the ideal has yet to be obtained. The food items were generally over-wrapped in some type of transparent flexible film, such as a cling wrap, shrink wrap or a perforated film, which prevents spattering and retains steam, which assists in heat transfer during microwave reheating.

Packaging materials represent a large proportion of the vended product cost in relation to other fields where little or no packaging is required. For example, a large triangular disposable microwavable dish cost 6.7p, which could represent as much as 10% of the product cost depending on the value of the product.

A variety of pre-plated meals limits customer choice. This may be partly overcome by vending vegetables in separate containers, but this then complicates the reheating procedure. Apart from greater product choice there are additional arguments for offering individual meal components. By only offering complete meals, the market is limited to those who can afford them and excludes those who may only wish to purchase 1 or 2 items. Thus `the build your own meal' concept allows for a greater variation in spending power.

Labelling is a fundamental part of full meal vending and is used to reveal the name of the product, sell-by-date or code and reheating instructions. Only seven of the organizations interviewed employed their own date stamping or coding system. As a marketing tool this is as yet a relatively unexplored area.

3.3.8. Distribution

All operators surveyed, who offered a vending service at a site distant from that of production delivered products on a daily basis with the exception of Sunday deliveries. Such frequent deliveries were necessitated by the short product shelf-life. Most operators only serve their locality (up to a radius of approximately 40 miles) as transport, particularly refrigerated transport, is expensive. Unit 14 had invested in a refrigerated vehicle and was therefore able to operate on sites up to 100 miles from its central kitchen. Only two other operators used refrigerated transport. During transport, products are liable to slip about in their containers and affect the standard of presentation.

3.3.9 Chilled food vending machines

Approximately 500 CFVM are sold annually in the UK. Unit 11 was the CFVM market leaders with approximately 55% of the market, (which had been reduced from 70% due to stiff competition). They sold one CFVM for every 10 beverage vendors. Unit 9 were the second market leader in CFVM's and had effectively marketed their chilled food vending machines as part of a complete staff feeding system and hence the food side of their business had grown at a faster rate than their drinks vending side. Their strength at the time of the study was staff feeding in hotels (unit 16; the Swiss Cottage Holiday Inn; Gleneagles and the Heathrow Hotel). Unit 9 were the largest British manufacturer of vending machines, but only had 10-12% of the CFVM market.

At present, there are two basic designs of machine; the drum vendor, which is the most common model and consists of several circular shelves attached together in a vertical column, each drum being divided up into individual compartments. Capacity depends on the size of drum and compartment. The products are illuminated by strip lighting inside the machine and may be viewed through a front glass

panel, which may be double-glazed. In the second type of machine the products are displayed on rectangular shelves, with all the products on view at any one time. Both designs incorporate a refrigeration and ventilation unit and may operate on either a coin or token mechanism, a cashless system (credit cards) or a `free vend' system.

Most chilled food vending machines are imported into Britain from America and Europe and the same machine model is often marketed under different names, according to the name of the distributor. Outlined below are the models available in the U.K..

The Wittenborg FM400 (Swedish)

The FM400 is a drum vendor, with up to 12 shelves, each consisting of 6-36 compartments. They are not able to accommodate a 9" plate. According to company literature it operates at between 5 and 8°C, which is achieved by $^{1}/_{3}$ H.P. compressor. The machine can only operate in `first-in-first-out' mode (FIFO), where each shelf contains the same product, as opposed to `shopper mode' where each shelf can carry a variety of products and any product may be selected. Thus FIFO limits the choice of products to up to 12 items in the FM400.

The Wittenborg New Model (launched in May 1985)

Wittenborg have designed a new model, which incorporates both shopper and FIFO modes, which is based on the drum concept and has a greater capacity than previous drum vendors. It is claimed to operate at a lower temperature (3°C) and due to better insulation and the more efficient circulation of air, the overall temperature control is claimed to be superior. The front glass panel is much larger than the current FM400 thus allowing greater visibility of products. The design of the glass front is unique, as it is a circular sliding door which slides to the side of the machine

when a vend is made. Another unique feature of the machine is its structure: the walls of the cabinet consist of two metal sheets, 1 mm thick, between which is an insulating material. It is therefore very light and easy to install, although, its lightweight construction offers very little resistance to vandalism.

The Superchef V72 (German)

Unit 9 market this drum vendor, which has a capacity for up to 72 meals and operates in 'shopper' mode. The openings to dispense food items are large enough to accomodate a 9" plate. The V72 is claimed to operate at a constant 4°C .

The Rowe 448 (USA)

The main distributors for this drum vendor are unit 10. It has a capacity of up to 77 main meals (11 shelves with 7 compartments) and accommodates a 9" plate, but may be arranged into other configurations. The modes of operation include 'shopper' mode or FIFO or a combination of both. The glass display allows 80% of the compartments to be on view at any one time, which is greater than the Wittenborg 400 and the Superchef V72. The Rowe 448 incorporates a `health timer', which overrides the temperature control for 30 minutes after closing the door following cleaning or loading, in order to allow the correct operating temperature to be obtained. After 30 minutes, if the temperature should rise above 7°C the machine will shut down until a temperature of 7°C is reached.

The MDM Venders RFM400\10\65 (Germany)

MDM Venders are a division of Moyer Diebel and distribute this machine in the U.K.. It is a drum vendor with a capacity of up to 40 main meals (9" plate). Refrigeration

is by a 1\2 H.P. compressor and the operating temperature is described as less than 10°C. A Health timer is included.

The Grand Gourmet CFM (USA)

National Vendors distribute this machine which is based on a rectangular shelf principle rather than a drum. There are four shelves each with up to 24 selections, all of which are on view at any one time through a large double glazed window. When the delivery door is open a lift dispenser moves up to seal off the delivery area from the main cabinet, reducing heat lost during removal of food items., The superior visual display has earned this machine the title `the Concorde of vending'. This is reflected in its price; £6,444 - January 1983 (National Vendors, 1983) as opposed to approximately £3,000 for drum vendors. Its dimensions are greater than the drum vendors and its weight is almost double (624 Kg), thus presenting installation problems. Due to the shelving it is only practical to use rectangular rather than circular dishes.

3.3.10. The `re-manufacture' of vending machines

The `re-manufacture' of old vending machines has become an industry in itself. Old vending machines are purchased, certain parts are replaced or rebuilt, the machines are painted and then sold with a guarantee. The re-manufactured machines are often considered to be superior to the new machines as certain inherent problems may be overcome during re-manufacture. There has been a tendency for operators to opt for refurbishment of existing units, rather than install new units with a resultant reduced demand for new machines. It is estimated that some re-manufactured machines in current use are over 20 years old (unit 3, 1982), whereas the operating life of a new machine is approximately 5 years, depending on the site. Some manufacturers, for example unit 9, now re-manufacture their own machines.

The light weight construction of the new Wittenborg drum vendor means that re-manufacture would be more difficult.

3.3.11. Maintenance of vending machines

Just under 50% of the questionnaire respondents cited breakdowns of machines as being a problem. An important role of the manufacturers or distributors is that of maintenance. Unit 9, unit 10 and unit 11 operate a national maintenance service. National Vendors have been criticized for not having an in-house maintenance service or guarantees for their machines. Several of the larger vending operators employ a team of engineers to service their own machines.

[1]3.3.12. Design,decor and siting of machines

Identical or similar machines from the same manufacturer may be banked together (modular), but between manufacturers sizes of machines are not standardized. The banking of machines is thought to improve the overall decor of the vending machines. Greater attention is now given to the siting of vending machines and also to the design and decor of the eating environment.

3.3.13. Queueing at machines

Each vend takes a minimum of 20 seconds and reheating takes on average 1 minute thus queuing at the machines may be a problem where mealbreaks are not staggered. At unit 4, several hundred workers all have the same 30 minute lunchbreak and are served by 3 CFVM's and 6 microwaves. In contrast at the unit 7 site there are 6 microwave ovens and 4 CFVM's for up to 90 meals between the hours of 11:30 to 1:30.

3.3.14. Attitudes to vending

Many operators believed the biggest problem in vending food is conceptual, the acceptability of using an impersonal machine in place of a personal service. Many operators are attempting to personalize their vending service by employing a 'hostess' during peak periods (unit 13, unit 14). Their duties include, assisting in the operation of machines and the reheating process, manually serving food in the event of a machine breakdown, dealing with minor problems on site, ordering food for that site, serving of sauces, preparation of filled rolls to order and frying and serving of chips.

Using a vending machine for the first time requires a certain amount of willingness on the part of the user to learn how to use it and obtain the desired product. The survey indicates that in general, Trade Unions resist the introduction of vending as they see it as a loss of personal services and a loss of jobs. When vending completely replaces a traditional service the demand for food often drops considerably (unit 13; unit 8).

A recent survey (NOP, 1983), found that the reasons people gave for not using vending machines were a) because they did not have access to any, b) where access was available the products were considered expensive and/or of poor quality. Vending was seen as part of people's modern day life and a necessary alternative to conventional systems. They were not thought difficult to operate, but even so only 5% of the sample said given a choice they would prefer to buy from a vending machine and only 1 in 4 agreed there should be more vending machines. There were mixed feelings about the freshness of the products, but generally the machines were thought to be clean, hygienic, reliable and well maintained. However refunds were thought difficult to obtain.

As vending machines are unmanned for the majority of the time, they are particularly vulnerable to vandalism. This vulnerability partly explains why full meal vending has, to

date, been limited to use with semi-captive markets rather than the general public.

3.4. Conclusions

Many of the advantages of a cooked food vending system are gained by the operator, (in particular, the reduced labour costs) while some of the disadvantages are borne by the customer, (for example reduced personal service and possibly poorer product quality). For the industry to develop this situation must alter. The consumer will only gain if a dependable 24 hour service offering value for money is offered and this therefore must be the goal of the FMV industry.

Distribution and storage of cooked menu items in CFVM's imposes increased rigours on product quality. This may be partly overcome by optimizing product quality by means of good hygiene, rapid chilling and maintaining an adequate cold-chain of distribution. The latter two practices, which are fundamental to the food manufacturing industry were found to be rare occurrences in the FMV industry, which suggests that overall product quality is inferior. If vending operators or caterers are having difficulty supplying the appropriate quality products as a result of insufficient resources or expertise, then this surely represents a new potential market for the food manufacturing industry which already supplies chilled produce to the retail market.

The opinion was often expressed in the survey that the public have different attitudes to chilled foods served from CFVM than to foods in retailers chilled cabinets. The reasons for this may be that when purchasing a meal to be consumed immediately as in a catering situation a "complete meal experience" is being bought as compared to simply buying the product in a retail outlet. Obviously, many factors in addition to product quality and which are in the realm of the caterer will influence the quality of the meal

experience. However, setting these factors aside, product quality in CFVM's must match or surpass that found in retail chill cabinets if full acceptance of FMV is to be achieved.

CHAPTER 4

A SURVEY OF THE OPERATING TEMPERATURES OF CHILLED FOOD VENDING MACHINES AND AN ASSESSMENT OF THE RISK OF GROWTH OF FOOD POISONING ORGANISMS.

4.1. Introduction

The growth of pathogens in foods represents a serious health hazard and the possibility of this occurring during storage in a CFVM must be established. Temperature is one of the major factors influencing microbial growth, as described in Section 1.2, Chapter 1, therefore the operating temperatures within the CFVM should be determined. This was the aim of the time temperature survey reported here. In order to predict the behaviour of food poisoning organisms at these temperatures, the individual growth characteristics of food poisoning organisms were reviewed, together with studies of their behaviour in foods under similar conditions of storage. This review is presented in Appendix three. A summary of the factors limiting growth of the major food poisoning organisms is presented in Table 4.1 and examples of the minimum temperature for growth for certain food poisoning organisms are given in Table 1.5.(Chapter 1).

This chapter combines the data on CFVM operating temperatures with the relevant information on food poisoning organisms in an assessment of the potential health risk.

Table 4.1. The growth characteristics of food poisoning organisms

Organism	Source	Heat Resistance	Limiting conditions for growth and toxin production			
			Temperature (°C)	Water activity	pH	% Na Cl in aqueous solution
Staphylococcu aureus	Man & Animals (nose, throat & skin)	Organism; moderate Toxin; high	Growth; < 7 Toxin production; < 10	Aerobic; < 0.86 Anaerobic; < 0.9	< 4.8	< 20%
Clostridium botulinum, Group I, type A, proteolytic strains of type F	Soil	Spores; high Toxin; low	< 10	< 0.94	< 4.5	8 - 10%
Group II, type E, non proteolytic, strains B and F	Soil, Marine sediments	Spores; moderate	< 3.3	< 0.95	< 4.5	5 - 6%
Clostridium perfringens	Soil, Water, Man, Animals (Intestinal tract)	Spores; high	Growth; < 15 Spore formation; < 27	<0.95	Growth; < 5.0 Sporulation; <6.7	< 8%
Salmonella	Man, Animals (Intestinal tract)	Moderate	< 6.7	< 0.94	< 4.5	< 8%

4.2. Methods: the survey of the operating temperatures of chilled food vending machines.

A time-temperature survey of the operating temperatures of CFVM's was undertaken using a Grant miniature temperature chart recorder (Grant Instruments, Cambridge), which is compatible with both the space restrictions and movement experienced within vending machines. Temperatures were recorded from two channels for 5 minutes in every hour, within a temperature range of -5 to +15^{o}C. The thermocouples were secured onto the left hand side wall of the cabinet; one in the upper half and and the second in the lower half. The position of the thermocouples were standardized for each model of CFVM. The recorded data was transcribed by means of a digitizing pad (Model HRD series, Terminal Data Systems, Blackburn, UK) and descriptive statistics prepared with the "statistical package for the social sciences" (SPSS) software package (Nie et al., 1975).

The eleven machines that were monitored are listed in Table 4.2.

Table 4.2. The models of chilled food vending machine monitored in the survey.

1. Rowe 448
2. Rowe 448
3. Rowe 448
4. Rowe 448
5. Rowe 448
6. Rowe snack machine
7. Wittenborg FM400
8. Wittenborg FM400
9. Roboserve
10. Roboserve
11. Grand Gourmet

4.3. Results and discussion.

All of the machines were monitored under normal operating conditions, with the exception of the first Rowe machine which was located in the laboratory and not in general use.

The second and third Rowe 448 machines were located on the same site and according to the management had different usage rates. The machine in most frequent use (number 2, Table 4.3) had the lower mean operating temperature and so the reported higher rate of use did not appear to be putting undue strain on the the refrigeration system.

The third Rowe 448 and the Rowe snack machine showed a difference between the upper and lower halves of the cabinet of 8 and 3°C respectively. The other Rowe machines maintained less than 1°C difference between the two sections. The two Wittenborg machines also showed similar large differences in mean operating temperature between different areas of the cabinet (Table 4.4). Where large differences occur this may have been due to the warmer air currents being generated from the strip lighting in the machine or insufficient cold air circulation.

Of the Rowe 448's, all the mean temperatures were below 5°C, with the exception of the upper half of the cabinet of the third machine. The mean temperatures of the Robserve machines were also below 5°C and within close proximity of each other, which indicates less variation of temperature within the cabinet and between machines (Table 4.5).

Table 4.3. The operating temperatures of the Rowe machines.

No 1	PROBE 1*	PROBE 2*
Mean temperature (°C)	3.39	3.25
Standard deviation	.97	1.09
% Readings < 0°C	0.0	0.0
% Readings > 5°C	1.20	1.20
% Readings > 10°C	.48	0.0
% Readings > 0 & < 3°C	35.42	41.45
Minimum temperature (°C)	1	1
Maximum temperature (°C)	15	7
Number of readings	415	415

No 2	PROBE 1	PROBE 2
Mean temperature (°C	2.92	2.54
Standard deviation	1.47	2.26
Readings < 0°C	1.40	18.88
Readings > 5°C	3.22	11.75
Readings > 10°C	0.0	.28
Readings between 0 & 3°C	48.25	31.19
Minimum temperature (°C)	-1	-3
Maximum temperature (°C)	6	11
Number of readings	715	715

No 3	PROBE 1	PROBE 2
Mean temperature (°C	11.65	3.59
Standard deviation	5.40	1.27
Readings < 0°C	2.24	0.0
Readings > 5°C	76.14	12.68
Readings > 10°C	72.56	0.0
Readings between 0 & 3°C	9.69	33.71
Minimum temperature (°C)	-1	0
Maximum temperature (°C)	15	7
Number of readings	1341	1341

No 4	PROBE 1	PROBE 2
Mean temperature (°C)	4.0	2.56
Standard deviation	1.08	2.31
Readings < 0°C	.08	19.25
Readings > 5°C	21.48	11.86
Readings > 10°C	0.0	.23
Readings between 0 & 3°C	23.17	30.72
Minimum temperature (°C)	-2	-5
Maximum temperature (°C)	6	15
Number of readings	1299	1299

No 5	PROBE 1	PROBE 2
Mean temperature (°C)	4.33	3.05
Standard deviation	1.27	2.72
% Readings < 0°C	.12	18.81
% Readings > 5°C	26.79	29.05
% Readings > 10°C	.60	.60
% Readings between 0 & 3°C	15.60	24.17
Minimum temperature (°C)	-1	-5
Maximum temperature (°C)	15	15
Number of readings	840	840

No 6 (snack machine)	PROBE 1	PROBE 2
Mean temperature (°C)	6.24	3.41
Standard deviation	1.11	2.18
% Readings < 0°C	0.0	2.96
% Readings > 5°C	87.89	22.82
% Readings > 10°C	.99	1.41
% Readings between 0 & 3°C	0.0	40.00
Minimum temperature (°C)	4	-1
Maximum temperature (°C)	13	15
Number of readings	710	710

* : Probe 1 was in the upper half of the cabinet and probe 2 in the lower half.

Table 4.4 <u>The operating temperatures of the Wittenborg FM400</u>

No 1	PROBE 1*	PROBE 2*
Mean temperature (°C)	7.59	4.51
Standard deviation	1.31	2.65
% Readings < 0°C	0.0	.21
% Readings > 5°C	99.72	44.44
% Readings > 10°C	.42	.07
% Readings between 0 & 3°C	.07	35.28
Minimum temperature (°C)	0	0
Maximum temperature (°C)	15	15
Number of readings	1440	1440

No 2	PROBE 1	PROBE 2
Mean temperature (°C)	9.06	2.47
Standard deviation	1.69	1.96
% Readings < 0°C	0.0	0.0
% Readings > 5°C	100.00	12.50
% Readings > 10°C	20.00	0.0
% Readings between 0 & 3°C	0.00	78.75
Minimum temperature (°C)	7	1
Maximum temperature (°C)	14	7
Number of readings		

* : Probe 1 was in the upper half of the cabinet and probe 2 in the lower half.

Table 4.5 The operating temperatures of the Roboserve machines

No 1	PROBE 1*	PROBE 2*
Mean temperature (°C)	4.28	4.08
Standard deviation	2.32	2.67
% Readings < 0°C	0.0	0.0
% Readings > 5°C	28.57	32.00
% Readings > 10°C	4.00	4.00
% Readings between 0 & 3°C	44.00	48.57
Minimum temperature (°C)	1	1
Maximum temperature (°C)	13	13
Number of readings	175	175

No 2	PROBE 1	PROBE 2
Mean temperature (°C)	4.34	3.59
Standard deviation	1.35	1.20
% Readings < 0°C	0.0	0.0
% Readings > 5°C	23.66	12.37
% Readings > 10°C	.86	0.0
% Readings between 0 & 3°C	13.07	33.39
Minimum temperature (°C)	0	0
Maximum temperature (°C)	15	6
Number of readings	1285	1285

* : Probe 1 was in the upper half of the cabinet and probe 2 in the lower half.

Table 4.6. The operating temperatures of the Grand Gourmet

	PROBE 1*	PROBE 2*
Mean temperature (°C)	8.47	7.24
Standard deviation	.75	1.20
% Readings < 0°C	0.0	0.0
% Readings > 5°C	100.00	96.80
% Readings > 10°C	1.33	.53
% Readings between 0 & 3°C	0.0	0.0
Minimum temperature (°C)	6	4
Maximum temperature (°C)	15	16
Number of readings	750	750

* : Probe 1 was in the upper half of the cabinet and probe 2 in the lower half.

Only one Grand Gourmet was monitored because of the lack of these machines in the South of England, as their distributing company is based in the North. The mean temperature of this machine tended to be higher than the

other machines surveyed and it remained above 5°C for 97% of the readings.

It is just as undesirable from the point of view of food texture for temperatures to drop below zero as it is for them to exceed 5°C from a microbiological point of view. The Roboserve and Wittenborg machines rarely recorded temperatures below 0°C, whereas the temperature of two of the Rowe 448 machines dropped below zero for 20 % of the readings.

Reasonable temperatures for storing cooked-chilled foods are considered to be between 0 and 5°C as these comply with the DHSS recommendations on cook-chill items (Chapter 1). However all of the CFVM were designed prior to the advent of the cook-chill system and so the attainment of temperatures below 3°C was probably not a priority. Basford (1963) suggests that manufacturers of CFVM's aimed to comply with article 25 of the Food Hygiene (General) regulations, even though they were not liable to. Table 4.7 shows the percent of readings from each machine that falls within these limits.

Table 4.7 The percent of recorded temperatures between 0 and 5°C.

		Probe 1	Probe 2
1.	Rowe 448	98.80	98.80
2.	Rowe 448	69.37	95.38
3.	Rowe 448	21.62	87.32
4.	Rowe 448	78.44	68.89
5.	Rowe 448	73.09	52.14
6.	Rowe snack machine	12.11	74.22
7.	Wittenborg FM400	0.28	55.25
8.	Wittenborg FM400	0.00	87.50
9.	Roboserve	71.43	68.00
10.	Roboserve	76.34	87.60
11.	Grand Gourmet	0.00	3.20

Of the machines in constant use the Roboserve machines were best able to maintain temperatures between 0 and 5°C, while the Grand Gourmet was the least satisfactory. The

limitations of such a study should be considered when interpreting the data; in particular the small number of each model monitored in the study and also the limited area within the cabinet where temperature was recorded. The Rowe 448 which was not in use was more efficient at maintaining constant temperatures. The decrease in efficiency found with the machines in constant use may have been due to the opening of compartment doors to remove products. The size of these openings vary with model type; the Roboserve and Rowe machines have small individual doors for each compartment in the drum, whereas with the Wittenborg machine a panel swings aside, revealing a complete vertical section of the drum, thus allowing more cold air to leave and warm to enter. This may account for the higher temperatures recorded in the Wittenborg machine as compared to the Roboserve and Rowe machines.

In a study of the Rowe 448 in the laboratory temperatures were recorded inside the compartments of the drum, both at the back and the front of the cabinet (Table 4.8). Large variations were found but overall the rear of the cabinet was a few degrees colder. In practice, food items would rarely be stored at either temperature for long periods of time as the drum would be frequently rotated by customers. The compartments within a drum vending machine are often panelled, which may restrict the flow of air, however they are designed to contain one product only, thus reducing the possibility of badly stacked items blocking air currents.

Table 4.8 The operating temperatures at the front and rear of a Rowe 448.

Front of cabinet

	PROBE 1*	PROBE 2
Mean temperature (°C)	5.71	3.91
Standard deviation	.98	1.40
% Readings < 0°C	0.0	0.0
% Readings > 5°C	76.92	30.77
% Readings > 10°C	0.0	0.0
% Readings between 0 & 3°C	3.85	30.77
Minimum temperature (°C)	3	2
Maximum temperature (°C)	7	6
Number of readings	26	26

Rear of cabinet

	PROBE 1	PROBE 2
Mean temperature (°C)	5.36	2.63
Standard deviation	1.80	1.44
% Readings < 0°C	2.38	4.76
% Readings > 5°C	73.81	0.0
% Readings > 10°C	0.0	0.0
% Readings between 0 & 3°C	8.73	49.21
Minimum temperature (°C)	-1	-2
Maximum temperature (°C)	7	5
Number of readings	126	126

* : Probe 1 was in the upper half of the cabinet and probe 2 in the lower half.

Table 4.9 The temperature of a chicken drumstick and the air temperature within a Rowe 448 .

	CHICKEN	AIR
Mean temperature (°C)	3.88	4.07
Standard deviation	.15	1.23
% Readings < 0°C	0.0	0.0
% Readings > 5°C	0.0	26.87
% Readings > 10°C	0.0	0.0
% Readings between 0 & 3°C	0.0	25.21
Minimum temperature (°C)	4	2
Maximum temperature (°C)	4	6
Number of readings	480	480

The difference between air and product temperature (chicken drumsticks) was also examined under experimental conditions (Table 4.9). The mean temperature of the chicken was lower than that of the air and showed far less variation.

The air temperature exceeded 5°C for 26% of the readings, which may be considered hazardous, however the product temperature did not exceed 5°C throughout the storage period of 96 hours. This indicates that temperatures may rise above 5°C for very limited periods without affecting the temperature of the food items in storage. In this experiment however the CFVM had only to maintain the low temperature in the food and not reduce the temperature, as the product was rapidly chilled to less than 3°C prior to storage. Test sandwiches prepared at 25.5°C and placed in a refrigerator at 7.2°C were still not below 10°C fifteen hours later (Tiedeman, 1958).

The number of bacterial outbreaks of food poisoning reported by the Public Health Laboratory Service increased in 1982 and 1983 as compared with the years 1977 and 1981 (CDSC, 1985). The number of cases in 1982 and 1983 are shown in Table 4.10. Thirty eight percent of general outbreaks followed meals at restaurants or receptions (Gilbert, 1985). In the UK Campylobacter enteritis has recently emerged as the most frequently reported form of acute bacterial diarrhoea, with 20,902 cases reported in 1984 (PHLS, 1984). Information is lacking but it is likely that transmission of the latter is mainly through the food chain from raw animal products. Campylobacter sp. can also survive in water for several weeks at low temperatures (Skirrow, 1982). Turnbull et al. (1982) found 1 % of 6,000 samples of red meats at retail distribution in the UK to be contaminated with the organism. Stern et al., (1985) found 30 % of chickens yielded the organism.

Table 4.10 Public Health laboratory reports of bacterial food poisoning and salmonella infection in England and Wales 1983 (1982 figures in parentheses).

Organism	All Cases	
S.typhimurium	6324	(4956)
Other salmonella sp.	6926	(6143)
C.perfringens	1624	(1455)
S.aureus	160	(89)
B.cereus and bacillus sp	134	(41)
	15168	12684

Source; Gilbert, (1985)

In the context of this study the area of concern is whether food poisoning could result from storage of food in a CFVM. Before that is answered, the possibility of pathogens being present in cooked food items should be considered. As shown in Table 4.1 food poisoning organisms are ubiquitous in nature and so most raw foods are likely to be contaminated to a greater or lesser extent. In raw foods, substantial growth is generally kept in check by the naturally occurring saprophytes that dominate that microflora.

As a result of cooking the microflora is usually reduced to heat resistant sporeformers and post heat treatment contamination may also occur and introduce a wider range of organisms. Whether food poisoning organisms will constitute a part of this microflora is largely dependent on the hygienic practices employed by the caterer. It must be assumed that any of the organisms that cause food poisoning are potentially present in small numbers in vended cooked menu items.

In general, for food poisoning to occur substantial growth of the organism in the food is required, as large numbers of salmonellae, staphylococci and clostridia are associated with their particular food poisoning syndrome. Therefore contamination of the food as such is rarely enough to cause food poisoning. Conditions conducive to the growth of these organisms is also required. Storage temperatures

within the CFVM are of critical importance. As shown in the review in Appendix 3 and in Table 1.5, Chapter 1, most food poisoning organisms are mesophiles and unable to grow below 5°C. Only 7 of the 11 CFVM's monitored had average temperatures below 5°C and there were considerable variations in temperature both within the same machine and between machines. It therefore cannot be guaranteed from these results that, had mesophillic foodborne pathogens been present, they would have been unable to grow. Searle and Crozier (1981) surveyed 559 refrigeration units in hotels, of which 19.7 % were found to be above recommended temperatures. The recommended temperatures varied with the use of the refrigeration unit, but were generally higher than the 5°C specified in the current study. The authors concluded that there were serious inadequacies in the management of low temperature food storage in the hotels and recommended implementing a control system to monitor temperature on a regular basis. Munce (1984) believed that the greatest hazard associated with the food service industry was the lack of food hygiene knowledge and motivation by food service managers and workers. The current study would suggest that CFVM's are capable of maintaining the correct storage conditions but management must be convinced of the importance of regularly ensuring that adequate chill temperatures are maintained rather than simply relying on the equipment.

The time taken for numbers of food poisoning organisms to reach the maximum stationary phase of growth will decrease with increases in temperature. For example, in pre-sterilized chicken gravy Staphylococcus aureus reached this phase in 6 days at 20°C, 15 days at 10°C and at 5°C numbers decreased (Kereluk et al, 1961). The duration of a safe storage time is therefore dependent on the storage temperature and so a CFVM operating at between 8 and 10°C may present no danger as long as foods are stored for no longer than a few hours, which was often the case in the British food vending industry (Chapter 3).

Psychrotrophic organisms responsible for food poisoning also exist. Clostridium botulinum type E must be of major concern because of its associated fatality rate. From 1899 to 1973 there were 1,784 cases of botulism and 978 deaths, the case fatality rate being 54.8 percent. According to Lucke (1981) psychrotrophic strains of Clostridium botulinum were of little relevance to meat products, as all psychrotrophic (non proteolytic) strains had been isolated from samples of aquatic origin, but not from meat or meat products and also because psychrotrophic strains are more sensitive to heat and curing salts than their mesophillic counterparts. Mead (1983) points out however that fishmeal is frequently used as poultry food so contamination with spores may not be ruled out. Foods of aquatic origin will be served from CFVM's.

The growth of other psychrotrophic pathogens in refrigerated cooked foods has also been demonstrated, for example Yersinia enterocolitica grew in cooked beef and pork at 7°C within 10 days (Hanna et al., 1977). Listeria monocytogenes has been isolated from various foods (Gilbert, 1985).

The minimum temperature for growth of an organism tends to be lower in bacterial media, than in sterile foods, which in turn is lower than in foods with a competing microflora. Growth in foods may be restricted by limiting growth conditions, such as reductions in the Aw or pH or an increased level of NaCl. These growth factors affect organisms differently (Table 4.1). For example, Staphylococcus aureus is able to tolerate lower Aw values as compared to most other organisms associated with foods (Minor and Marth, 1976, Broughall et al., 1983). Partly because of this Stiles et al., (1979) found that Staphylococcus aureus was more capable of growing in vacuum packed bologna than Bacillus cereus, Clostridium perfringens, Escherichia coli and Salmonella typhimurium.

Unfortunately, it is rare that cooked menu items have pH values, salt concentrations or Aw that completely inhibit

growth of pathogenic bacteria, which means that inhibition of their growth will depend on other factors, suh as microbial competition, storage atmosphere and most relevant of all to this survey, temperature.

The majority of organisms associated with food poisoning appear to be poor competitors. This is largely because in raw foods the naturally occurring microflora generally have a lower optimum growth temperature and are therefore able to grow more rapidly and compete for nutrients more effectively. Their growth may also result in a drop in pH or production of inhibitory compounds. The growth of lactic acid bacteria in particular is often reported as being inhibitory towards the growth of clostridia, Staphylococcus aureus, and salmonellae (see appendix 3 for further details). Cooking will eliminate the level of microbial competition, therefore making conditions more suitable for the growth of pathogens. Products may possibly be safeguarded against the growth of pathogens by the addition of a harmless microflora, such as lactic acid bacteria. At present very little work has been done in this field in respect of cooked menu items.

Reports on the effect of storage atmosphere on the growth of pathogens vary, possibly because of differences in product type and hence pH, Aw and also differences in the competing flora present. Nielsen and Zeuthen (1984) studied the growth of several pathogenic bacteria (Yersinia enterocolitica, Staphylococcus aureus, Bacillus cereus, Salmonella typhimurium and enteritidis) on bologna at refrigeration temperatures in packs of different gas permeabilities. They concluded that the gas permeability of the packaging film is of only minor importance, whereas temperature was very important. Goepfert and Kim (1975) also found that packaging films of different permeabilities did not influence the behaviour of Escherichia coli, enterococci, salmonellae, staphylococci, Bacillus cereus and Clostridium perfringens.

Hanna et al., (1977a) found the inhibitory effect of vacuum packaging on the growth of Y. enterocolitica on raw beef stored at 2.5°C to be considerable. The authors suggested that this may have been due to the presence of a normal spoilage flora on the beef, which would have been suppressed on the vacuum packed samples, allowing lactic acid bacteria to predominate, which would have produced the inhibitory effect.

The effect of CO_2 is also variable; salmonellae and Staphylococcus aureus are inhibited in the presence of high levels of CO_2, whereas it produces a stimulatory effect on the germination of Clostridium perfringens spores at atmospheric pressure and an inhibitory effect at hyperbaric pressures (Enfors and Molin, 1978).

Conditions within the CFVM may not permit growth of most pathogenic bacteria, but some will survive, which represents a potential hazard, as vended items may be subjected to abuse after purchase. Stiles and Ng (1979) simulated contamination of hams with pathogenic bacteria and determined its food poisoning potential under abusive and ideal conditions of storage and handling. After 30 days at 4° and 10°C Staphylococcus aureus, Escherichia coli and Salmonella typhimurium had survived, but numbers had decreased slightly. The samples were then held for 24 hours at 30°, 21° and 4°C in normal atmosphere to simulate sandwich handling. This resulted in the growth of Staphylococcus aureus to potentially hazardous levels at the higher temperatures.

4.4. Conclusions

The importance of proper temperature control is as critical in chilled food vending as in any other sector of catering. This study shows that CFVM's are able to maintain temperatures below 5°C, as recommended for cook chill menu items, although this temperature was not universally found.

Modifying the storage atmosphere of a cooked menu item may delay microbiological spoilage, if the cooked food was contaminated with saprophytes after cooking (Chapter 5), but it cannot be assumed that the risk of growth of food poisoning organisms also is reduced, and in the absence of a competing flora proper temperature control is even more essential.

CHAPTER 5

THE EXAMINATION OF THE NATURALLY OCCURRING MICROFLORA OF COOKED CHILLED MENU ITEMS.

5.1. Introduction

The aim of the microbiological investigations was to examine the effect of packaging, storage time and temperature on the type and number of micro-organisms present in the food product.

The investigation was divided into a pilot study and a major study. The purpose of the pilot study was to examine different methods in order to obtain the most effective approach, in terms of a) reproducibility of results, b) elimination of confounding variables and c) minimizing the time and materials involved. Roast chicken portions and cottage pies were chosen for analysis and were prepared under both simulated and actual conditions of food preparation. The effect of varying chill storage temperature on the developing microflora of the refrigerated menu items was examined. The times and temperatures of incubation of bacterial growth media plates were varied. A further pilot experiment looked at the effect of the type of chicken portion i.e. muscle type, on the total numbers of bacteria developing during storage.

The major study covered two areas; first, the examinination of the naturally occurring microflora developing on cooked menu items as a result of storage conditions and second, the direct inoculation of cooked menu items with bacterial isolates recovered from previously stored samples. The storage conditions of interest were type of packaging, temperature of storage and time of storage.

The packaging types of interest included cling wrap, vacuum packaging and modified atmosphere packaging. Cling

wrap film is commonly used in catering and vending situations in order to prevent product dehydration, eliminate microbial cross-contamination and enhance product display. Vacuum packing has been used by caterers for packaging cooked foods, such as entree dishes, which are pasteurized after packing (Bjorkman and Delphin, 1966; Minor, 1972; Paulus et al., 1979). Under chilled storage conditions, pasteurized vacuum packed foods have been found to provide a longer shelf-life than untreated foods (Lott, 1973; Pinaga et al., 1979; Paulus et al., 1979). Post packing pasteurization of foods is unlikely to be applicable to plated meals served from CFVM as many of these items contain salad components or are bread based. An alternative to vacuum packing is modified atmosphere packing (MAP), which involves the flushing of packs with a combination of N_2, CO_2 and O_2. The combination of gases depends on the product type and the desired microbial and sensory effect. For example, in order to preserve the red colour of fresh beef O_2 must be present, whereas the flavour of pork is preserved in the absence of O_2 as it is liable to promote oxidative rancidity due to the high level of saturated fats found in pork. The advantages of MAP are increased shelf-life of certain products, minimal damage to fragile foods otherwise crushed by vacuum packing and the opportunity of improved presentation. MAP has been used for retailing raw meats and fish, cured and fermented meat products, bakery goods and cheeses (Anon, 1984).

The effect of packaging and temperature on microbial growth has been reviewed in Chapter 1.

5.2. Materials and methods

5.2.1. Pilot study

5.2.1.1. Preparation of cooked menu items

The preparation of cottage pie under simulated processing conditions and the preparation of roast chicken under simulated and actual processing conditions are described in Appendix 2.

5.2.1.2. Conditions of storage in the pilot experiment

To examine the effect of storage at 4 ± 1°C on the developing microflora of cooked menu items, cottage pies and chicken portions were stored unwrapped in a Gallenkamp chilled incubator at 4 ± 1°C for up to 13 days. On days 0, 3, 4, 5, 6, 10, 11, 12, and 13 one portion of each product was removed for analysis.

Similarly, the effect of storage at 0 ± 1°C was examined in a second experiment by storing samples of cottage pies and chicken portions, which were wrapped in cling film wrap prior to storage in a chilled incubator for up to 15 days. The cling wrap was supplied by Perfawrap, High Wycombe, UK and had the following transmission rates, O_2; 5400cc/m2/24 hours, water vapour; 90g/m^2/24 hours and CO_2; 35000 cc/m2/24 hours. On days 0, 1, 4, 5, 6, 8, 9, 11, 12, 13, 14 and 15 one portion of each product was removed for analysis.

In a duplicate experiment chickens were prepared in hospital kitchens in order to more closely simulate industrial preparation conditions. The chickens were portioned and placed in individual containers and wrapped in cling film at the hospital, prior to being transported back to the laboratory and placed in the blast chiller for 90 minutes. From the time the chickens were removed from the

oven at the hospital to the time they were placed into the chiller was no longer than 70 minutes. The original cling wrap film was removed prior to storage due to excessive condensation and the samples were rewrapped and placed in chilled incubators operating at either 0 ± 1°C or 4 ± 1°C. On days 0, 1, 4, 6, 7, 8, 11, 12, 13, 14, 15, 18 and 19 one chicken portion was removed from storage for analysis.

The effect of muscle type on the developing microflora of cold chicken was investigated by examining different portions of the same chicken prepared and stored under the same conditions. A single chicken was prepared, roasted and chilled by the methods described previously. The chicken meat and skin was aseptically removed from each chicken portion and finely chopped, in order to equally distribute the micro-organisms present. The chopped meat from each portion was replaced in the polypropylene container in which it had been chilled and wrapped in cling film. The five minced portions were stored in a chilled incubator at 4 ± 1°C. On days 0, 5, 8, 12, 16 and 19 of storage, one 10g sample of minced chicken was removed from each of the five minced chicken samples for analysis.

5.2.1.3. <u>Microbiological analyses</u>

Three samples of 10g each were removed from the whole chicken portions and contained approximately equal quantities of skin and flesh.

The cottage pies were mixed with a fork and 3 samples of 10g each were taken.

The samples were each added to 90 mls 1/4 strength Ringers solution (Oxoid) and homogenized in a Colworth stomacher for 30 seconds. Appropriate dilutions of the homogenate were made in 1/4 strength ringers and plated onto plate count agar (PCA; Oxoid) to determine total plate counts (TPC). Plates were incubated aerobically at 30°C for 1 day

and also at 7°C for 10 days for the first two experiments. The 0.1 ml surface spread plate method of plating was used.

For samples prepared at the hospital, PCA plates were incubated aerobically at 30°C for 1 day and 20°C for 72 hours on all sampling days and anaerobically (Oxoid anaerobic system) at 20°C for 72 hours on the first and last days of storage. The composition of the microflora of chicken samples prepared in the hospital kitchen were further analysed on the first and last day of storage by the use of additional growth media to determine:

1. Pseudomonas on Pseudomonas selective media with CFC supplement (PSM; Oxoid),

2. Clostridia on reinforced clostridial media (RCM; Oxoid),

3. Total coliforms in MacConkey broth (Oxoid) and

4. Bacillus spores according to the method of Patterson and Gibbs, (1973).

In addition, 30 colonies were randomly selected from PCA plates by means of a Harrison disc (Harrigan and McCance, 1976). The plates were obtained from a freshly cooked and chilled sample, a sample stored at 0°C for 19 days and a sample stored at 4°C for 19 days. Isolated colonies were examined for; cellular morphology, gram stain reaction, motility, ability to use glucose, catalase reaction, oxidase reaction and the ability to hydrolyse arginine.

The pH of the tenfold dilution of the samples prepared at the hospital was recorded by with a Uniprobe pH meter, model 310D (Uniprobe Instruments Ltd., Cardiff).

Two way analysis of variance was undertaken on the TPC of chicken drumsticks prepared at the hospital and stored at 0 and 4°C (Snedecor and Cochran, 1967).

5.2.2. Major study: the effect of packaging, storage time and temperature on the naturally occurring microflora in cooked menu items.

5.2.2.1. Preparation of menu items and packaging procedures.

Deep fried chicken drumsticks and chicken a la king were prepared and either cling wrapped or vacuum packed or packed under modified atmosphere according to the methods described in Chapter 2. Ingredients for the menu items were purchased in advance (with the exception of the fresh vegetables in the chicken a la king). The meats were purchased frozen from Dorset Poultry Packers, Upton, UK and held at below -20^{o}C until required.

5.2.2.2. Storage conditions

Packaged samples were stored at either 4 ± 1^{o}C, 0 ± 1^{o}C in Gallenkamp chilled incubators or at a variable 4^{o}C in a Rowe 448 CFVM. The operating temperature of the vending machine was monitored by a Grant miniature temperature recorder.

5.2.2.3. Microbiological analyses

Products were stored for up to 21 days, during which time four samples of each product were removed for analysis on at least 10 separate occasions, including the day of production and the last day of storage. MAP and vacuum packed chicken drumsticks were also analysed after 60 days storage at 4 ± 1^{o}C. Each packaging treatment was examined in a separate experiment, giving three experiments in total.

The first experiment looked at the effect of cling wrap film and employed two different sampling techniques for the chicken drumsticks:

1) chicken meat was minced aseptically after frying and chilling and samples of minced chicken were stored and used for subsequent analysis.

2)whole drumsticks were packaged as described in Section 2.3 and after the appropriate storage period the surface of the drumstick was removed for sampling. The surface consisted of either skin or flesh to a depth of 2 - 3 mm.

The second method was adopted for further experiments as it more clearly indicates changes in surface growth.

The samples were diluted tenfold in 0.1% peptone (pH 7.0) and blended in a Colworth Stomacher. This first dilution was used to prepare 1 ml and 0.1 ml surface spread plates on PCA and also PCA plates prepared by the spiral plate technique (Gilchrist et al., 1973) using a "Spiral Plater" available from Don Whitley Scientific, Shipley, W.Yorkshire. Colonies on the spiral plates were counted using a calibrated grid. PCA plates were incubated aerobically at 20°C for 72 hours.

The composition of the microflora was analysed intermittantly by the use of selective growth media to determine:

1. <u>Pseudomonas</u> on <u>Pseudomonas</u> selective media with CFC supplement (PSM;Oxoid). Plates prepared on the spiral plater and 1ml and 0.1ml spread plates were incubated at 20°C for 72 hours.

2. Clostridia on sulphite polymyxin sulphadiazine (SPS; Difco). 1ml pour plates were prepared and incubated anaerobically at 37°C for 7 days.

3. Lactobacilli on Mann Rogosa and Sharpe agar (MRS; Oxoid). 1ml layer plates were prepared and incubated anaerobically at 30°C for 3 days.

4. Yeasts and moulds on oxytetracycline glucose yeast extract agar (OYGE; Oxoid). 1ml pour plates were incubated aerobically at 20°C for 5 days.

5. Brochothrix thermosphacta on STAA agar (Gardner, 1966)

The pH of the tenfold dilution of each sample was recorded as described in Section 5.2.1.5.

5.2.3. Major study: the effect of packaging on the growth of Pseudomonas and Lactobacilli species on deep fried chicken drumsticks.

5.2.3.1 Preparation of inoculum

Two cultures were selected for examination. A strain of Pseudomonas and a strain of Lactobacilli, both of which were isolated during previous experiments. Both colonies were examined for cellular morphology, gram stain reaction, oxidase reaction, catalase reaction and ability to use glucose. The Lactobacilli was further examined for production of CO_2 from glucose, production of ammonia from arginine and growth at 37 and 45°C. The Pseudomonas was examined for hydrolysis of arginine, fluorescent pigment and by inoculating API20E galleries (API Laboratory Products Ltd., Basingstoke, UK) for the identification of Enterobacteriaceae and other gram negative rods.

Both organisms were grown at 20°C in 10 mls nutrient broth supplemented with 0.25% glucose. The cultures were centrifuged at 3,000 g for 10 minutes and the liquid decanted. The supernatant was washed in 0.1% peptone, centrifuged as before and resuspended to a total volume of 10

mls. Appropriate dilutions were prepared in 0.1 % peptone from which 0.1 ml PCA spread plates were prepared and the optical density read at 650 nm. A standard curve was prepared showing bacterial concentration against optical density.

5.2.3.2 Preparation and inoculation of samples

Chicken drumsticks were prepared by the methods described in Section 2. The inoculum was prepared as before and diluted to give 10^5 to 10^6 organisms per ml. The surface of the chilled drumsticks was inoculated with 1ml of either inoculum by means of a sterile glass rod and template (surface area; 18 cm^2). The drumsticks were then either cling wrapped, MAP or vacuum packed. Uninoculated drumsticks were also packaged for use as controls. All samples were stored at $4 \pm 1^{o}C$ in an incubator for 21 days.

5.2.3.3. Microbiological analyses

Four drumsticks from each treatment (cling wrapped, MAP or vacuum packed and also uninoculated or inoculated with either Lactobacilli or Pseudomonas) were examined on days 0, 4, 7, 14 and 21 days.

Any off odours present on opening the packs were noted and the surface pH recorded by means of a surface electrode. The surface of the same area that had been inoculated was cut away for sampling, diluted tenfold in 0.1 % peptone and homogenized for 30 seconds in a Colworth Stomacher. PCA plates were prepared and incubated as described in Section 5.2.2.3.

The selective media PSM with CFC supplement was used to determine the number of Pseudomonas present on the control samples on the first and last day of storage and on the drumsticks inoculated with Pseudomonas throughout storage. Similarly, MRS agar was used to determine the number of

Lactobacilli present on the control samples and samples inoculated with Lactobacilli. Plating methods and incubation times are given in Section 5.2.2.3.

5.3. Results and discussion

5.3.1. The pilot experiments

During the pilot experiments TPC were made under different incubation conditions (mesophilic counts at 30°C for 24 hours or 20°C for 48 hours, psychrotrophic counts at 7°C for 7 days or 4°C for 14 days). Both sets of incubation conditions yielded similar results, as shown in Tables 5.1 and 5.2. Due to the variability in the results, consistent differences between incubation temperatures were difficult to demonstrate. For further experimental work 20°C for 48 hours was chosen as it gave maximum cell numbers throughout the storage period and by incubating plates at one rather than two temperatures the work load was reduced by half.

The TPC of the chicken portions and cottage pie stored at 0 and 4°C are shown in Tables 5.1 and 5.2. A distinct and continuous log phase was not apparent in the data.

Table 5.1. Mesophilic and psychrotrophic counts * of roast chicken portions and cottage pie stored at 4°C.

	ROAST CHICKEN		COTTAGE PIE	
Day	Mesophiles	Psychrotrophs	Mesophiles	Psychrotrophs
0	<3.47	<3.47	<3.47	<3.47
3	<3.47	<3.47	<3.47	<3.47
4	4.55	<3.47	<3.47	<3.47
5	<3.47	<3.47	<3.47	<3.47
6	<3.47	<3.47	<3.47	<3.47
7	8	6.16	4.2	4.28
10	7.94	8.3	ND	4.47
11	ND	ND	5.72	5.684
12	5.64	5.85	5.63	5.72
13	ND	ND	<3.47	<3.47

* : means of $\log_{10}$ (n=3)/g, following incubation at 30°C / 24 hours (mesophiles) or 7°C / 10days (psychrotrophs).
ND: no data available

Table 5.2. Mesophilic and psychrotrophic counts * of roast chicken portions and cottage pie stored at 0°C.

	ROAST CHICKEN		COTTAGE PIE	
Day	Mesophiles	Psychrotrophs	Mesophiles	Psychrotrophs
0	3.81	<3.47	<3.47	<3.47
1	<3.47	<3.47	<3.47	<3.47
4	4.21	3.65	<3.47	<3.47
5	4.14	3.98	<3.47	<3.47
6	4.14	3.69	4.74	4.38
7	4.54	4.54	3.64	3.5
8	4.73	4.55	<3.47	<3.47
9	5.07	ND	<3.47	<3.47
11	5.02	5.11	5.71	ND
12	5.2	5.32	4.5	4.39
13	6.6	6.67	3.68	<3.47
14	ND	ND	3.62	<3.47
15	7.31	ND	3.9	3.7

* : means of $\log_{10}$ (n=3)/g, following incubation at 30°C / 24 hours (mesophiles) or 7°C / 10days (psychrotrophs).
ND : no data available

However, it appears that storage at 4°C produced a faster logarithmic growth rate than at 0°C, as higher TPC's were attained at an earlier stage at 4°C, indicating an inhibitory effect of reducing temperature from 4 to 0°C.

This trend agrees with reports in the literature on the effect of reducing temperature (Section 5.1.1). They should however be interpreted with care as certain factors may be identified that would contribute to experimental error and hence cause in part the variation in results that was found. Unwanted variability in all the experiments may have been due to the following reasons. Substantial differences were found between pH of leg muscle (6.6 - 6.8) and breast and wing muscle (5.9 - 6.1). As the type of muscle varied between sampling days the pH would have fluctuated, resulting in variations between samples. Other differences in muscle type may have also modified the nature of the microflora. The storage experiments at 0 and 4^{o}C were undertaken on two separate occasions, which would have resulted in differences in the type and number of micro-organisms at the beginning of storage, which would in turn influence the nature of the developing microflora. The sampling method involved taking three samples from one portion, thus limiting the population from which the samples were drawn.

A range in the TPC of roast chicken portions was also apparent in the samples prepared at the hospital and analysed by the same methods (Table 5.3). Reasons for this variation have been discussed previously. As the samples stored at 0 and 4^{o}C were prepared simultaneously analysis of variance of the results was appropriate and the difference between the storage temperatures was found to be significant at the 1 % level.

Table 5.3 Mesophilic counts * of roast chicken portions prepared in a hospital kitchen and stored at 0 and 4°C.

	ROAST CHICKEN	
Day	0°C	4°C
0	4.61	4.61
1	4.5	4.7
4	4.32	3.86
6	4.4	5.23
8	4.6	4.68
11	<3.47	4.14
12	5.04	3.63
13	4.57	5.0
14	4.04	7.0
15	<3.47	6.14
18	6.11	3.74
19	4.54	4.14

*: means of $\log_{10}$/g (n=3), following incubation at 20°C / 72 hours.

The initial TPC were greater in samples prepared in actual food preparation conditions (Table 5.3) than in those prepared under simulated conditions (Table 5.1 and 5.2). The composition of the microflora of these samples was also examined before and after storage. Before storage, counts on all selective media were negligible. After storage the only selective media to produce growth was PSM, thus indicating growth of Pseudomonas, but not of coliforms, lactobacilli or clostridia.

Of the 30 colonies isolated from the chicken portion at the beginning of storage all were gram positive, non-motile, catalase positive cocci and were tentatively identified as staphylococci and micrococci (Table 5.4). As these organisms are relatively heat sensitive their presence is likely to have been due to contamination after initial cooking.

After storage 83% of isolated colonies were gram negative motile rods (Table 5.5). The change in the microbial composition from gram positive cocci to gram negative rods possibly Pseudomonas species which are frequently associated

with the spoilage of fresh foods) demonstrates the selective effect of chilled storage on the nature of the microflora in fresh food. This important change in the microflora was not reflected in the TPC which was similar on day 19 as it was on day 0. This emphasizes the importance of demonstrating the nature of the microflora either by the use of selective growth media or by isolating and identifying colonies.

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Table 5.4 Identification of 30 colonies isolated from freshly cooked chicken.

Morphology	Gram stain reaction.	Motility	Catalase reaction	Attack on glucose	Arginine hydrolysis	Colony No.
Cocci	Positive	Non motile	Positive	Fermentative	Negative	1, 5, 8, 12, 14, 19, 21, 22, 23, 24, 26, 29, 30,
	"	"	"	Oxidative	Positive	2, 28,
	"	"	"	"	Negative	3, 4, 6, 7, 9, 10, 11, 13, 15, 16, 17, 18, 20, 25, 27

Table 5.5 Identification of colonies isolated from cooked chicken stored for 19 days at 0 or 4°C..

Morphology	Gram stain reaction.	Motility	Attack on glucose	Oxidase reaction	Arginine hydrolysis	Colony No.
Organisms isolated from chicken stored at 4 o C.						
Rods	Negative	Motile	Oxidative	Positive	Positive	2, 7, 18, 27, 29
"	"	"	"	"	Negative	1, 3, 4, 8, 9, 11, 12, 14, 16, 19, 20, 21, 22, 23, 24, 25, 26,
"	"	"	"	Negative	Negative	6, 10, 25,
"	"	"	Fermentative	Positive	Negative	5, 12, 15, 28
"	"	Non motile	Oxidative	Positive	Negative	13, 30,
Cocci	Positive	Non motile	Oxidative	Positive	Negative	17

Morphology	Gram stain reaction.	Motility	Attack on glucose	Oxidase reaction	Arginine hydrolysis	Colony No.
Organisms isolated from chicken stored at $0^{o}C$.						
Rods	Negative	Motile	Oxidative	Positive	Positive	3, 8, 29, 18
"	"	"	"	"	Negative	13, 14, 20,
"	"	"	Fermentative	Positive	Positive	4, 5, 7, 9, 11, 19, 24, 26,
"	"	"	Fermentative	Positive	Negative	6, 11, 14, 17,
"	"	"	"	Negative	Positive	15
"	"	"	"	"	Negative	2, 12,
Cocci	Positive	Non motile	Fermentative	Positive	Negative	1, 10, 21, 22, 23, 27, 30,

In order to eliminate experimental error in the major experiment, it was decided to limit the chicken samples to one muscle type and to improve the experimental design by increasing the individual sample size and the number of samples and comparing products at all three storage temperatures simultaneously. It was not possible at this stage to consider examining all packaging types at the same time as the size of the experiment would have become unmanageable. Thus the precision in measuring the effect of temperature was increased by the partial sacrifice in precision of measuring the effect of packaging.

Microbial growth as indicated by TPC was greater in the leg portions than the wing or breast portions of whole roast chicken as shown in Table 5.6. In raw chicken bacterial growth appears to be much less over the breast than the legs (Barnes, Impey and Parry, 1973). This effect may have been due to the greater pH found in leg muscle as noted previously. In pure culture studies, using raw minced chicken breast and leg muscle, Barnes and Impey (1968) showed that strains of Acinetobacter groups B and C failed to grow in breast muscle (pH 5.7 to 5.9) during storage at 1 OC but grew readily in leg muscle (pH 6. to 6.7), whilst the growth of

Alteromonas putrefaciens was much faster in leg than in breast. Similarly, Mead (1969) found that sporulation of several strains of Clostridium perfringens including other heat resistant food poisoning types was generally 10 - 100 times greater in leg than in breast muscle of chicken. According to Pooni and Mead (1984) the substrate effect with raw chicken would seem to be much less than the effect on the growth of Pseudomonas of either storage temperatures or initial levels of contamination.

Table 5.6. Effect of storage at 4°C on mesophilic plate counts (log_{10}/g) in minced chicken portions.

Day	First leg	Second leg	First wing	Second wing	Breast
0	<3.47	<3.47	<3.47	<3.47	<3.47
5	4.4	<3.47	<3.47	<3.47	<3.47
8	4.5	<3.47	<3.47	<3.47	<3.47
12	7.0	4.0	5.0	<3.47	<3.47
16	6.9	6.8	<3.47	<3.47	<3.47
19	7.3	7.5	7.5	<3.47	7.1

It was decided to limit further experiments on whole chicken pieces to the leg portion as they supported more microbial growth than other muscle types. Leg portions were also thought appropriate as they are commonly served from CFVM (Tuck Shoppe, 1982).

5.3.2. The effect of packaging, storage time and temperature on microbial growth in cooked menu items

Two food products, typical of cooked food items currently served from CFVM's (Tuck Shoppe, 1982) and identified as potentially high risk products with respect to organoleptic changes, were chosen for subsequent analysis. These were deep fried chicken drumsticks and chicken a la king. Chicken a la king is a composite product and would be expected to contain higher initial numbers of of

micro-organisms than the drumsticks, thereby increasing the liklihood of contamination. Microbial growth would be expected to be limited to the surface of the drumsticks, whereas it would be expected to occur throughout the chicken a la king. Chicken has been shown to be a good growth medium at chill temperatures (Barnes, 1976) and has been used in previous microbiological studies (cooked chicken; Toule and Murphy, 1978; Patterson and Gibbs, 1973, chicken a la king; Angelotti et al., 1961).

The composition of the atmosphere used for the modified atmosphere storage was 70% CO_2 rather than 100% CO_2, in order to reduce the effect of pack collapse common when 100% CO_2 is employed (Anon, 1984). The difference was made up by N_2.

5.3.2.1. <u>The temperature of the CFVM.</u>

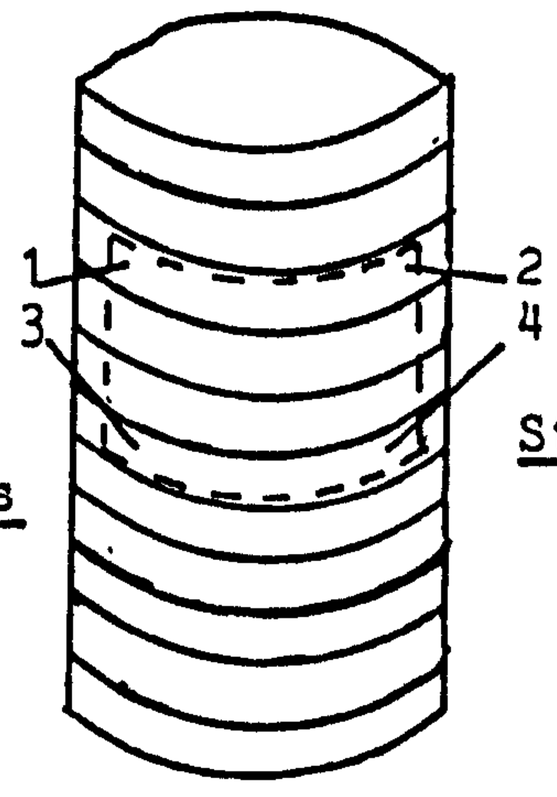
The temperature of the chilled food vending machine was lower during the first packaging experiment, as indicated in Table 5.7. At the lower thermostat settings, as used in the cling wrap trial, temperatures at some locations cycled between just above and just below $0^{o}C$. This led to excessive condensation on the display window of the cabinet, partial freezing of the products and also required that the refrigeration unit be defrosted regularly. Such a situation was thought to be unrealistic of a typical vending operation and therefore the temperature was adjusted to eliminate the possibility of a freeze-thaw cycle occurring.

At both thermostat settings the range of the mean temperatures was approximately $2^{o}C$, which is not substantial when compared with 2 to $13^{o}C$ as found in a catering department cold store (Toule and Murphy, 1978) and the ranges of temperature found in the survey of CFVM's described in Chapter 4.

Table 5.7 Operating temperatures (^{o}C) of the CFVM used to store samples.

Experiment one:		Storage of cling wrapped minced drumsticks and chicken a la king.			
Position of samples within cabinet		TEMPERATURE ^{o}C Thermocouple numbers 1	2	3	4
Front	Mean	0.9	1.7	1.2	2.0
	Standard deviation	1.3	0.8	0.8	0.6
Rear	Mean	0.6	0.03	0.5	0.05
	Standard deviation	1.1	2.0	1.2	1.6

Experiment two:		Storage of cling wrapped whole drumsticks and vacuum packed chicken a la king and drumsticks.			
		1	2	3	4
Front	Mean	5.3	5.1	3.8	5.3
	Standard deviation	0.8	1.0	1.4	0.8
Rear	Mean	3.2	3.4	3.2	3.0
	Standard deviation	2.0	1.2	1.7	1.8



5.3.2.2. Drumstick sampling method.

A destructive rather than non destructive method of sampling the whole drumsticks was decided upon. In a number of studies it has been shown that macerating samples gives a higher recovery of organisms than any other technique (Barnes et al., 1973). Patterson (1972) found swabbing of the skin did not give as good recovery as when the skin sample was removed and shaken in diluent.

Differences were found between the two drumstick sampling methods employed in the cling wrap experiment. As might be expected, the initial numbers of micro-organisms were higher in the minced chicken, due to the additional post cooking handling it received, even though the utmost care had been taken to mince the drumsticks aseptically and the larger surface area available for growth (Figure 5.1, graphs 1 and 2). The TPC in the minced chicken decreased after the first two days of storage, which possibly indicates that mesophiles were present initially and were inhibited by the chill temperatures, prior to an increase in TPC due to the growth of psychrotrophs.

The lag phase was shorter for the minced product, two days for the minced drumsticks at $4^{o}C$ and nine days for the whole drumsticks. By the end of the storage period, TPC for the whole product ranged between log 5.2-6.0 /g, whereas for the minced product they were at least log 7.0/g and therefore substantially larger (Figure 5.1 and 5.2).

Figure 5.1 Total plate counts* of chicken drumsticks

* mean of log10/g, n=4

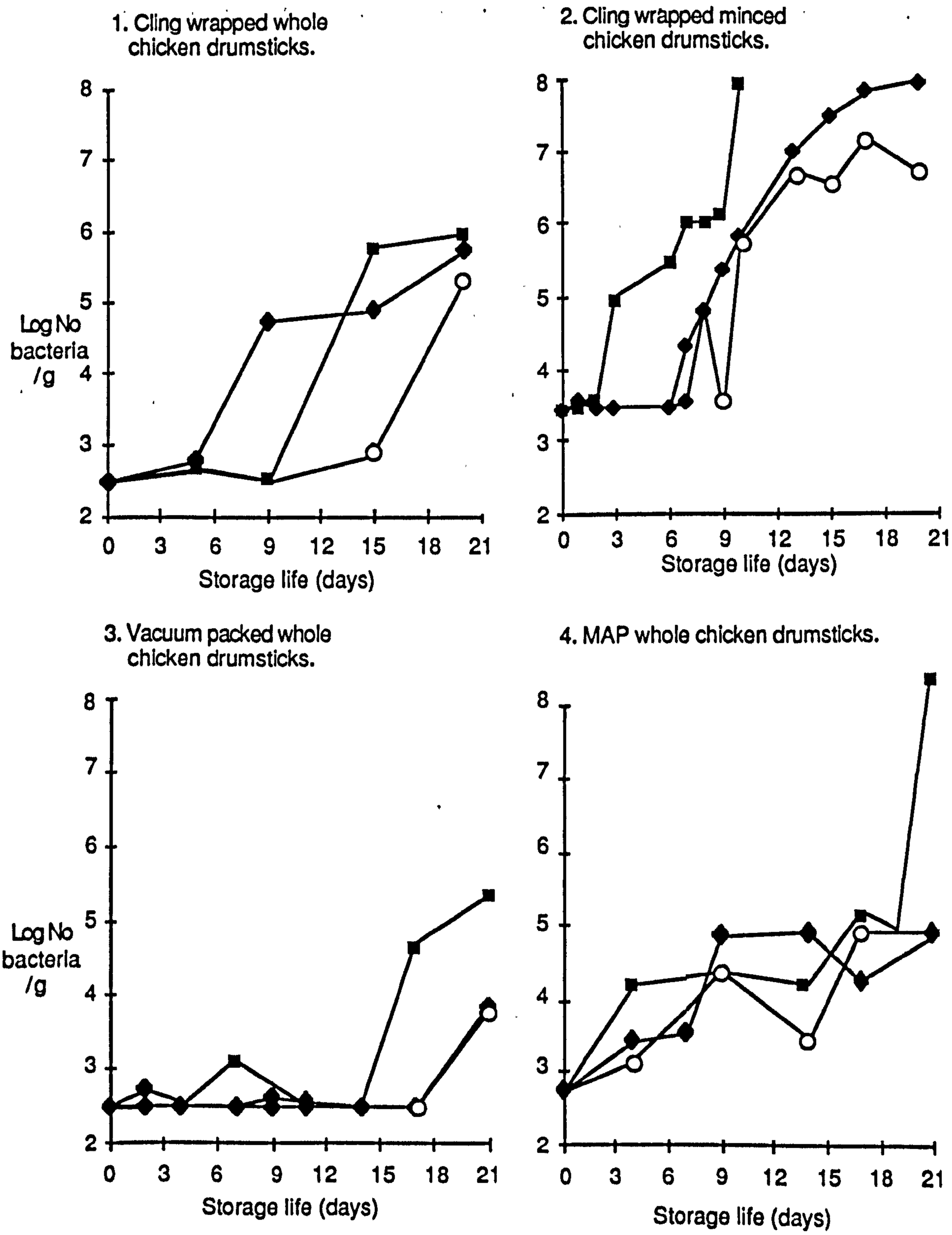
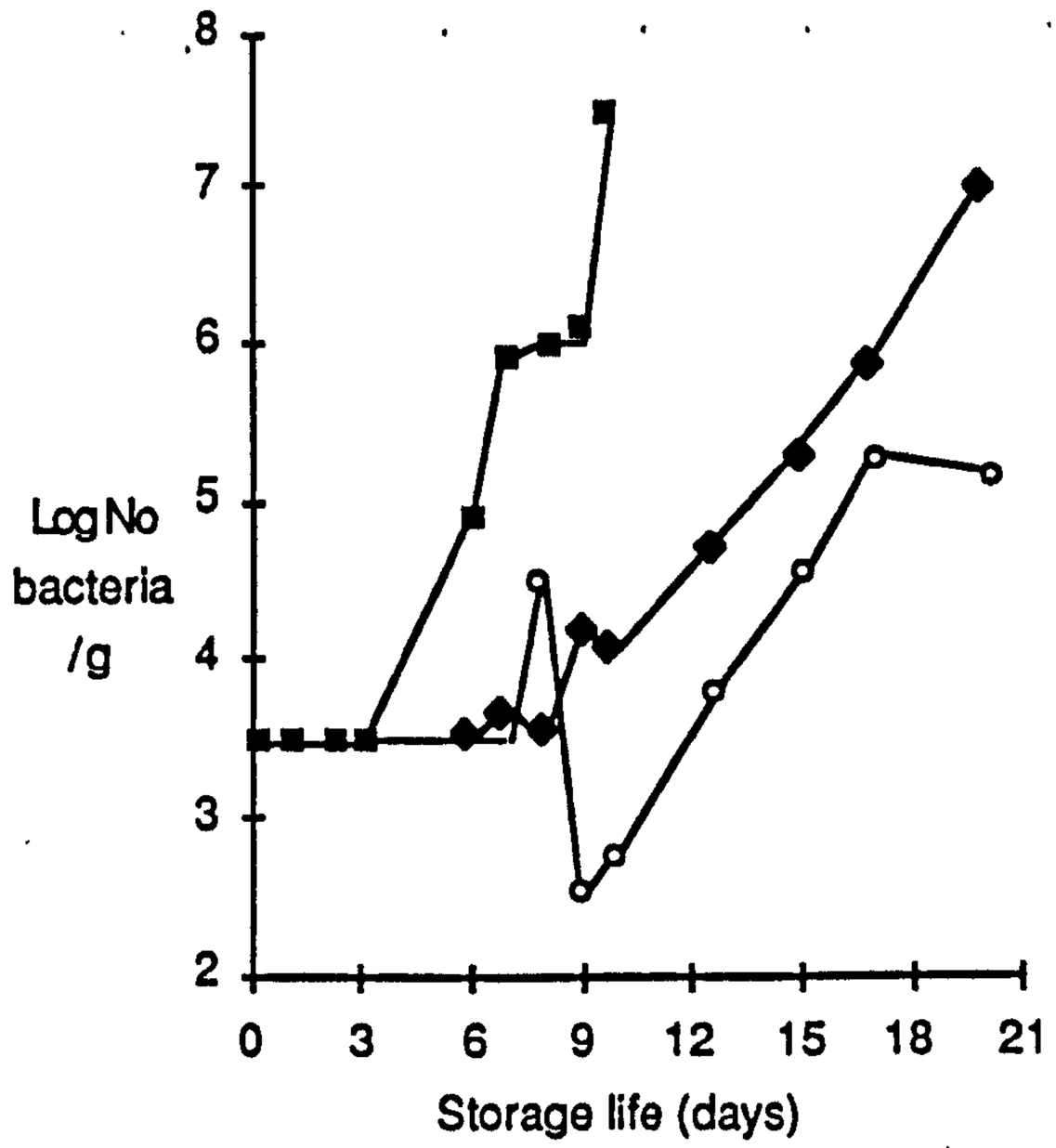


Figure 5.2 Total plate counts* of chicken a la king.

* mean of log 10/g, n=4

1. Cling wrapped chicken a la king.



2. Vacuum packed chicken a la king

The differences in results between sampling methods may be partly explained by the differences in microflora composition of the two products. By day 20, the microflora of the minced drumsticks stored at all temperatures contained a large proportion of Pseudomonas species (log 7.0-7.5/g), as shown by growth on PSM (Table 5.8), whereas only one whole drumstick sample , which was stored at 0°C, recorded growth on this media (Table 5.9 (5.8/g)) and consequently had the highest plate count at 0 °C . The absence of Pseudomonas species in whole drumsticks would partly account for the lower TPC. Lactobacilli counts were higher in the whole drumsticks, perhaps due to a lack of competition from the Pseudomonas species (Table 5.9).

The whole drumstick sampling method was adopted for the other packaging trials as this product was the form currently found in CFVM's and contrasted well with the chicken a la king.

Table 5.8 Bacterial counts * of cling wrapped minced chicken drumsticks stored at 0 and 4°C and in a CFVM (*: mean of $\log_{10}$/g, n=4).

Conditions of storage	Storage time (days)	Plate counts Average	Plate counts Range	Lacto -bacilli	Pseudo -monas	Yeasts & moulds	Clostridia
Vending machine	0	3.46	<2.47-3.64		<3.47	<2.47	<2.0
	1	3.55	<3.47-3.73				
	2	<3.47	<3.47				
	3	<3.47	<3.47		<3.47		
	6	<3.47	<3.47				
	7	4.31	3.88-4.55				<2.47
	8	4.83	4.49-4.95				
	9	5.36	4.3 -5.6				
	10	5.81	5.26-6.02	3.78	4.6->4.77		
	13	7.0	6.84-7.27		6.28	<2.0	
	15	7.49	6.95-7.88				
	17	7.84	7.81-7.9		7.48		
	20	7.98	7.95-8.0	<2.47-3.7		3.79	
0°C	0	3.46	<3.47-3.64		<3.47	<2.0	<2.47
	1	3.53	<3.47-3.66				
	2	<3.47	<3.47				
	3	<3.47	<3.47		<3.47		
	6	<3.47	<3.47				
	7	3.54	<3.47-3.61				<2.47
	8	4.79	4.4-5.01				
	9	<3.47	<3.47				
	10	5.71	5.5-5.86	2.98->4.77	>4.77		
	13	6.71	6.36-6.9		<5.84-6.4	<2.0	
	15	6.52	3.4-6.83				
	17	7.2	7.0-7.9		7.1		
	20	6.7	6.43-6.94	<2.47-3.5		2.0	
4°C	0	3.46	<3.47-3.64		<3.47	<2.0	<2.47
	1	3.51	<3.47-3.62				
	2	3.65	<3.47-3.83				
	3	4.98	4.1 -5.38		<3.47		
	6	>5.46	5.46->6.0				
	7	>6.0	>6.0			<2.47	
	8	>6.0	>6.0				
	9	>6.14	6.14- TNTC				
	10	>7.95	7.85- TNTC		3.81->4.7		>4.7

TNTC - too numerous to count

Table 5.9 Bacterial counts[a] of cling wrapped whole drumsticks stored at 0 and 4 °C and in CFVM.
(a: mean of $\log_{10}$/g, n=4).

Conditions of storage	Storage time (days)	Plate counts Average	Range	Lacto -bacilli	Pseudo -monas	Yeasts & moulds	Clostridia
Vending							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	5	2.77	<2.47-3.0				<2.47
	9	4.73	<2.47-5.3	<2.47->4.0	<2.47->4.0		
	15	4.9	<2.47-5.4				
	20	5.7	4.68-6.04	<2.47->4.0	<2.47->4.0	<2.0	
0°C							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	5	2.64	<2.47-2.9				<2.47
	9	2.49	<2.47-2.5	<2.47	<2.47->4.0		
	15	2.9	<2.47-3.27				
	20	5.26	<2.47-5.8	<2.47->4.0	<2.47->4.0	<2.0	
4°C							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	5	2.67	<2.47-3.0				<2.47
	9	<2.47		4.2	<2.47->4.0		
	15	4.0-5.8					
	20	5.98	3.1-6.3	<2.47->4.0	<2.47->4.0	3.7	

Table 5.10 Bacterial counts* of cling wrapped chicken a la king stored at 0 and 4°C and in a CFVM
(*: mean of $\log_{10}$ per g, n=4).

Conditions of storage	Storage time (days)	Plate counts		Lacto -bacilli	Pseudo -monas	Yeasts & moulds	Clostridia
		Average	Range				
Vending	0	<3.47			<3.47	<2.0	<2.47
	1	<3.47					
	2	<3.47					
	3	<3.47			<3.47		
	6	<3.47					
	7	<3.7	<3.47-4.0				<2.47
	8	<3.47					
	9	<4.19	<2.47-4.87				
	10	<4.07	<2.47-4.39	<2.47	<3.47-4.0		
	13	4.85	4.35-5.14		4.33->4.7	<2.0	
	15	<5.36	<3.47-5.9				
	17	5.94	4.36-6.18		5.38		
	20	7.06	6.5-7.27	<2.47->4.7		<2.0	
0°C	0	<3.47			<3.47	<2.0	<2.47
	1	<3.47					
	2	<3.47					
	3	<3.47			<3.47		
	6	<3.47					
	7	<3.47				<2.0	
	8	4.5	<3.47-4.8				
	9	<2.47					
	10	<2.75	<2.47-3.14	<2.47	<3.47-4.0		
	13	<3.87	<2.47-4.32		<3.47-4.0	<2.0	
	15	4.50	2.89-4.97				
	17	5.30	4.23-5.7		5.53-6.04		
	20	5.19	5.10-5.25	<2.47		<2.0	
4°C	0	<3.47			<3.47	<2.0	<2.47
	1	<3.47					
	2	<3.47					
	3	<3.47			<3.47		
	6	4.90	4.37-5.17				
	7	5.92	5.37->6.0				<2.47
	8	>6.00					
	9	>6.00			>4.77		
	10	>7.50		>4.0			

5.3.2.3. Effect of temperature.

a) In cling wrapped samples

The cling wrapped chicken a la king and minced chicken drumsticks clearly demonstrated a shorter lag phase at 4°C as compared to 0°C (Figures 5.1 and 5.3). For the chicken a la king the difference in the lag phase was approximately 8 days and for the minced chicken it was 4 days. Once growth commenced in the minced chicken held at 0°C it continued at a similar rate as growth at 4°C, suggesting the presence of psychrophiles or psychrotrophs able to grow at either temperature. These organisms were most likely to be Pseudomonas species as the TPC and counts on PSM were similar (Table 5.8). In the cling wrapped chicken a la king the logarithmic growth rate was slower at 0°C than at 4°C, which demonstrates an inhibitory effect of reducing temperature on microbial growth.

The effect of storage temperature was not as obvious on the TPC of the whole chicken drumsticks as in the minced samples (Figure 5.1, Table 5.10). The lag phase was greater at 0°C than at 4°C, but after 20 days storage the TPC were similar and approximately one hundred fold lower than in the minced chicken. The reasons for these differences were discussed in the previous section (5.3.2.2.).

b) In vacuum packed samples

In the vacuum packed samples the effect of temperature was reduced. In the chicken a la king the difference between the lag phase at 0 and 4°C had become negligible and the TPC at 0 and 4°C were approximately within one log cycle of each other at all temperatures (Table 5.11, Figure 5.2). The vacuum packed whole chicken drumsticks stored at 4°C had a lag phase of 13 days, which was increased to 17 days at 0°C. After 21 days storage the TPC at 4°C were 5.5 $\log_{10}$/g as compared to 3.8 $\log_{10}$/g at 0°C (Table 5.12). As growth in the log phase at 0°C was only recorded for a few days at the end of storage it is not possible to compare logarithmic growth rates.

Table 5.11 Bacterial counts * of vacuum packaged chicken a la king stored at 0 and 4°C and in a CFVM (*: mean $\log_{10}$ per g, n=4).

Conditions of storage	Storage time (days)	Plate counts	Lacto -bacilli	Pseudo -monas	Yeasts & moulds	Clostridia
	Average	Range				
Vending						
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	2	<2.47					
	4	<2.47					<2.47
	7	<2.47		<2.47	<2.47		
	9	<2.47					<2.47
	11	<3.10	<2.47-3.6			<2.0	
	14	<3.56	<2.47-4.1	<2.47	<2.47		
	17	<3.73	<2.47-4.3				
	21	<5.00	<2.47-5.6	<2.47	<2.47	<2.0	<2.47
0°C							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	2	<2.47					
	4	<2.47					<2.47
	7	<3.07	<2.47-3.6	<2.47	<2.47		
	9	<2.47					<2.47
	11	<2.47				<2.0	
	14	<2.47		<2.47	<2.47		
	17	<3.53	<2.47-4.1				
	21	4.10	<2.47-4.6	<2.47	<2.47	<2.0	<2.47
4°C							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	2	<2.47					
	4	<2.47					<2.47
	7	<2.47		<2.47	<2.47		
	9	<2.47					<2.47
	11	2.49	<2.47-2.5			<2.0	
	14	2.75	<2.47-2.9	2.5	<2.47		
	17	4.61	2.60-5.0				
	21	5.36	4.80-5.7	2.9	<2.47	2.74	<2.47

Table 5.12 Bacterial counts* of vacuum packaged chicken drumsticks stored at 0 and 4°C and in a CFVM.
(*: mean of $\log_{10}$/g, n=4).

Conditions of storage	Storage time (days)	Plate counts Average	Plate counts Range	Lacto -bacilli	Pseudo -monas	Yeasts & moulds	Clostridia
Vending							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	2	<2.47					
	4	<2.47					<2.47
	7	<2.47		2.54	<2.47		
	9	<2.62	<2.47-2.89				<2.47
	11	<2.55	<2.47-2.73			<2.0	
	14	<2.47		<2.47	<2.47		
	17	<2.47					
	21	3.86	2.60-3.04	<2.47	<2.47	<2.0	<2.47
0°C							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	2	<2.7	<2.47-2.89				
	4	<2.47					<2.47
	7	<2.47		<2.47	<2.47		
	9	<2.47					<2.47
	11	<2.47				<2.0	
	14	<2.47		<2.47	<2.47		
	17	<2.47					
	21	<3.8	<2.4-4.86	<2.47	<2.47	<2.0	<2.47
4°C							
	0	<2.47		<2.47	<2.47	<2.0	<2.47
	2	<2.47					
	4	<2.47		<2.47	<2.47		<2.47
	7	<3.07	<2.47-3.5				
	9		<2.47->4.0				
	11	<2.47				<2.0	
	14	<2.47		2.5	<2.47		<2.47
	17	4.74					
	21	5.4	3.10-5.90	2.99	<2.47	<2.1	<2.47
	60	7.65	5.68-8.05	6.00	<2.47		STAA : 6.34

c) In MAP samples

In the MAP chicken a la king growth was initiated after 11 days at 4°C, but the TPC did not exceed 4.5 $\log_{10}$/g and in fact the TPC dwindled towards the end of storage (Table 5.13). No growth occurred at 0°C until day 21 when the TPC was 3.86 $\log_{10}$/g as compared to 3.74 $\log_{10}$/g at 4°C.

In the MAP chicken drumsticks the lag phase at all storage temperatures was less distinct than in previous experiments. At 4°C the TPC rose to above 4.0 $\log_{10}$/g after four days and remained at this level until 20 days, when they rose slightly to 5.3 $\log_{10}$/g. The TPC at 0°C was always within one log cycle of the TPC at 4°C.

The TPC of products stored at the variable temperature in the CFVM generally mirrored the corresponding TPC's at either 0 or 4°C (Figures 5.1 and 5.2).

Table 5.13 Bacterial counts* of MAP chicken a la king stored at 0 and 4°C and in a CFVM

(*: mean of $\log_{10}$ per g, n=4).

Conditions of storage	Storage time (days)	Plate counts		Lacto -bacilli	Pseudo -monas	Yeasts & moulds	B. thermos -phacta
		Average	Range				
After cooking		<2.47		<2.47	<2.47	<2.47	<2.47
Vending							
	4	<2.47					
	7	<2.47		<2.47	<2.47		
	11	<2.47				<2.47	<2.47
	14	<2.47		<2.47	<2.47		
	17	<2.57	<2.47-2.78				<2.47
	19	<2.47					
	21	<2.47	<2.47-2.78	<2.47	<2.47		<2.47
0°C							
	4	<2.47					
	7	<2.47		<2.47	<2.47		
	11	<2.47				<2.47	<2.47
	14	<2.47		<2.47	<2.47		
	17	<2.51	<2.47-2.60				<2.47
	19	<2.47					
	21	<3.86	<2.47-4.45	<2.47	<2.47		<2.47
4°C							
	4	<2.47					
	7	<2.47		<2.47	<2.47		
	11	<2.47				<2.47	<2.47
	14	<3.43	<2.47-3.78	3.25	<2.47		
	17	<4.41	<2.47-4.72				<2.47
	19	<4.07	<2.47-4.62				
	21	<3.74	<2.47-4.34	3.74	<2.47		<2.47

Table 5.14 Bacterial counts* of MAP chicken drumsticks stored at 0 and 4°C and in a CFVM
(*: mean of $\log_{10}$ per g, n=4).

Conditions of storage	Storage time (days)	Plate counts		Lacto -bacilli	Pseudo -monas	Yeasts & moulds	B. thermos -phacta
		Average	Range				
After cooking	2.75			<2.47	<2.47	<2.47	<2.47
Vending							
	4	3.16					
	7	3.86		<2.47	<2.47		
	9	4.37					<2.47
	14	3.43			<2.47	<2.47	
	18	4.91		<2.47			
	21	4.91			<2.47	<2.47	<2.47
0°C							
	4	3.43					
	7	3.55		<2.47	<2.47		
	9	4.85					<2.47
	14	4.89			<2.47	<2.47	
	18	4.24		<2.47			
	21	4.82			<2.47	<2.47	<2.47
4°C							
	4	4.22					
	7	4.33		<2.47	<2.47		
	9	4.37					<2.47
	14	4.22			<2.47	<2.47	
	18	5.18		<2.47			
	21	4.92			<2.47	<2.47	
	60	8.39	5.85-8.57	<4.67			<2.47

The effect of reducing temperature in increasing the length of lag phase and reducing microbial growth in chicken a la king was greatest in the cling wrapped products and less in the MAP and vacuum packed products. In the cling wrapped product the lag phase is extended from 5 to approximately 10 days and the growth rate reduced at 0°C, whereas in the MAP and vacuum packed products the difference in lag phase and growth rate is relatively less. One reason for this could be that the aerobic strains of bacteria growing in the cling wrapped samples were more susceptible to changes in temperature than those strains in the MAP and vacuum samples. These results agree with the work of Spahl et al., (1981) who found a temperature increase from 2 to 5°C resulted in a greater increase in growth of psychrotrophic organisms on pork chops in the control environment (air) than in the CO_2 containing environments. In contrast, Nielsen (1983) found that aerobic plate counts and counts of Brochothrix thermosphacta of vacuum packed bologna sausage at 2 and 5°C were similar.

5.3.2.4. The effect of packaging on growth curve characteristics

MAP and vacuum packing also appear to exert their own inhibitory effect on microbial growth. For example in Figure 5.7. the cling wrapped chicken a la king has a shorter lag phase and faster growth rate than the MAP or vacuum packed samples stored at the same temperature. Also, the TPC at the end of storage is at least one hundred fold greater in the cling wrapped samples than the MAP or vacuum packed products. This effect is less apparent at 0°C.

5.3.2.5. The composition of the microflora at the beginning and end of storage.

With the exception of MAP drumsticks, bacterial counts of other products were below the level of sensitivity of the

tests at the beginning of storage (Tables 5.8, 5.9 and 5.10). This indicates that only small numbers of micro-organisms survived the cooking process and there was a low level of post cooking contamination.

The composition of the initial microflora present is undetermined as virtually no colonies grew on the selective media (less than 5 colonies per plate). A TPC below 100/g of cooked chicken was reported by Davidson and Webb (1973). The group of organisms present included Pseudomonads, Acinetobacter, microbacteria and coliforms, and were most likely post processing contaminants as the product was heated to 70°C and non sporing species such as these would have been destroyed. Throughout the storage period no clostridia were detected on any of the samples. Patterson and Gibbs (1973) detected small numbers of clostridial vegetative cells on freshly cooked chicken. After 21 days storage at 1 - 3°C no viable clostridial cells or spores could be detected. The absence of clostridia in the present study suggests a sufficient heat treatment was applied to destroy those present on the raw food and either a lack of post processing contamination or the maintenance of adverse conditions for the growth of clostridia (temperature of storage, microbial competition etc.).

In the cling wrapped chicken a la king and minced chicken there was a steady increase in counts on PSM, which corresponded with an increase in TPC (Tables 5.8 and 5.10). Small numbers of Lactobacilli were present on some of the cling wrapped samples on the last day of storage (2.47 to 3.7 $\log_{10}$/g). At the end of storage of cling wrapped minced chicken and chicken a la king the microflora was dominated by Pseudomonas species.

No Pseudomonas species grew or were detected on the vacuum packed products (Table 5.11 and 5.12), which agrees with results from previous investigations on fresh poultry (Shrimpton and Barnes, 1960, Jones et al., 1980).

After 21 days storage of vacuum packed chicken a la king the only growth on MRS agar was at 4°C, which represented a small proportion of the total population. Little or no growth occurred on the other selective media and so the dominating bacterial species remains unknown. By the sixtieth day of storage the number of Lactobacilli on the vacuum packed chicken drumsticks had risen to 6.0 $\log_{10}$/g, but were still tenfold less than the TPC. Davidson and Webb (1973) found the microflora of vacuum packed cooked chicken to be dominated by lactic acid bacteria after storage at 7, 24 and 37°C. For these samples counts were also made on STAA agar for the determination of numbers of Brochothrix thermosphacta and 6.0 $\log_{10}$/g were detected. Brochothrix thermosphacta was not present on MAP drumsticks of the same age, but numbers of Lactobacilli were similar to the TPC (Table 5.14) and therefore Lactobacilli dominated the microbial population.

The differences in effect of packaging on microbial growth in the two products are partly due to the different nature of the initial microflora. Had Pseudomonas species been present on the cling wrapped whole drumsticks, the TPC at the end of storage may have been greater, thus showing a greater difference between the cling wrapped and the MAP and vacuum packed samples. For this reason it was decided to conduct a further experiment to demonstrate the effect of packaging on the growth of specific micro-organisms.

5.3.3. The effect of packaging on the growth of a species of Pseudomonas and Lactobacilli.

Chicken drumsticks were chosen for this study as they had previously presented inconclusive results as to the effect of packaging. By inoculating samples with known numbers and types of micro-organisms prior to storage, the composition of the initial microflora could be standardized.

As both organisms had been isolated from cooked chicken (Toule and Murphy, 1978; Davidson and Webb, 1973) they were

thought to be representative of potential post cooking contaminants. Two strains of bacteria were chosen for study; first, a strain of Pseudomonas, which was the predominant micro-organism on the cling wrapped products at the end of storage and was isolated from a chicken drumstick stored at $0^{o}C$ for 19 days (Section 5.3.1). Secondly, a strain of Lactobacilli was isolated from an MRS agar plate prepared from a vacuum packed drumstick stored for sixty days at $4^{o}C$.

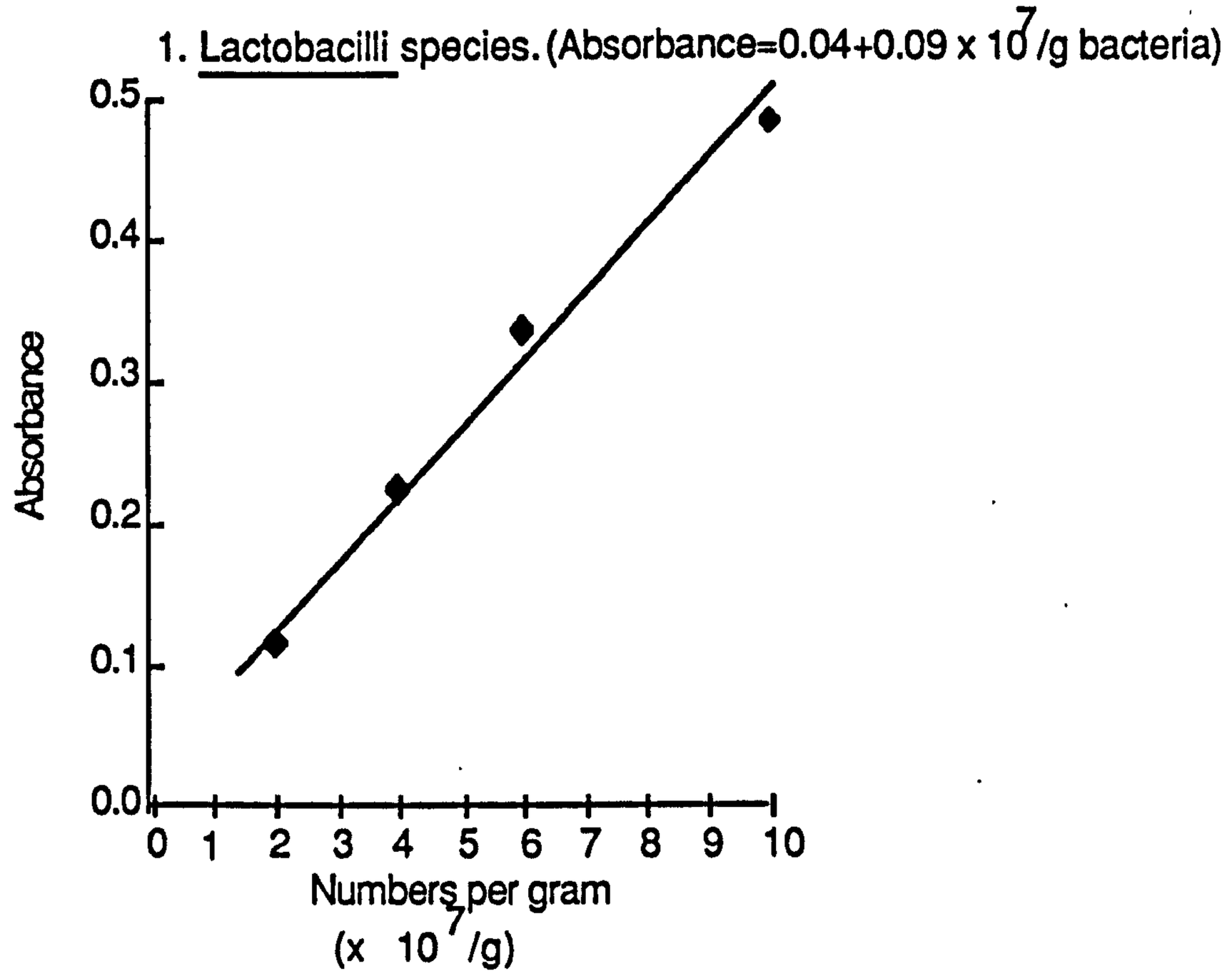
The species of Pseudomonas used in this study was gram negative, motile, oxidative, catalase positive, oxidase positive, hydrolysed arginine and did not fluoresce under ultra violet light. It was identified as "Pseudomonas fluorescens, excellent identification" according to the API20E system. Several workers have reported that most pseudomonads on meat are non-fluorescent (Shaw and Latty, 1981)

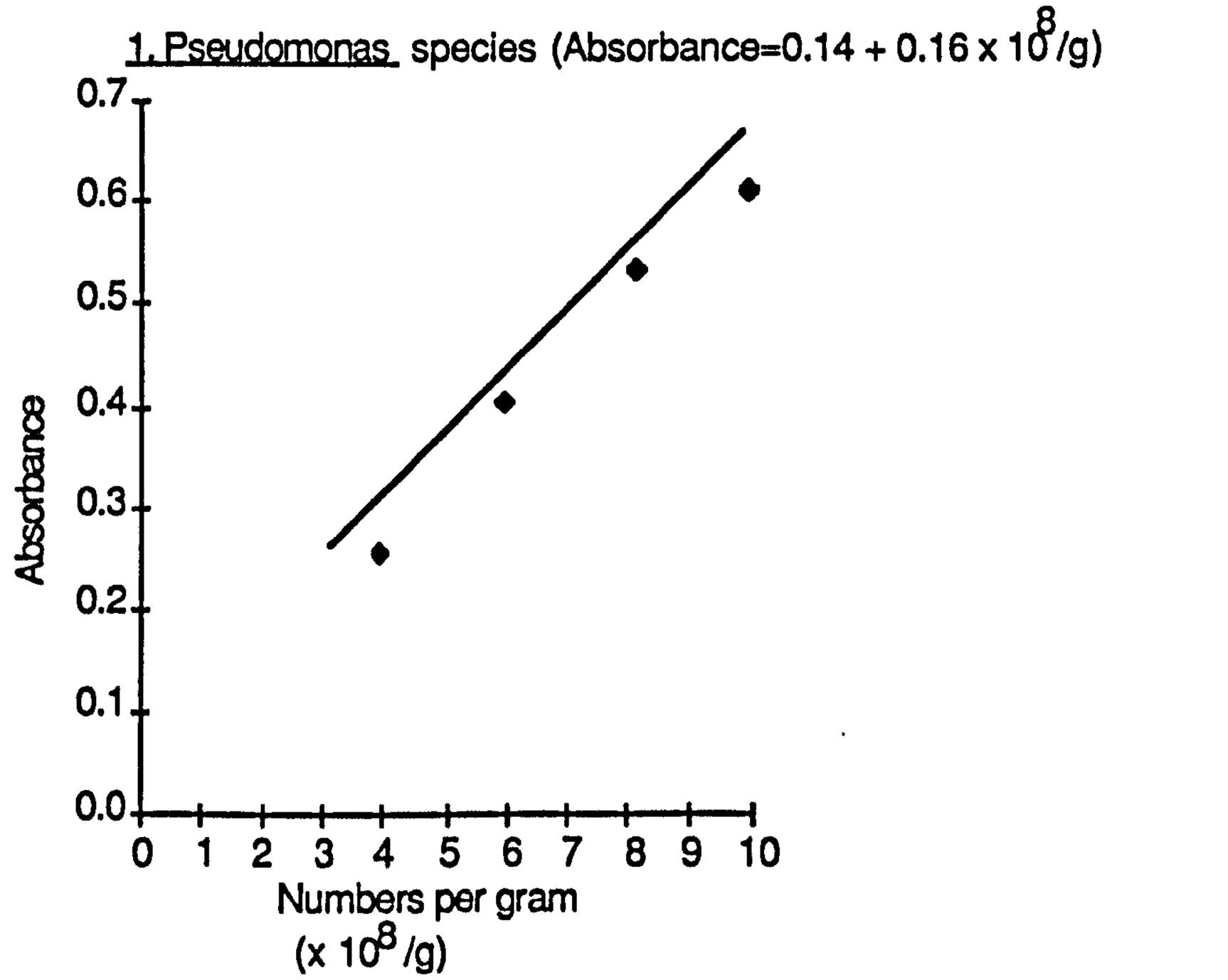
The strain of Lactobacilli occurred as stubby cocci, was non motile, gram positive, catalase negative and oxidase negative. As it produced gas from glucose, ammonia from arginine and grew at $37^{o}C$ but not at $45^{o}C$, it was thought to be a betabacterium (heterofermentative).

The level of inoculum was kept as low as possible whilst still remaining detectable as in all previous experiments the size of the initial microflora was small. The two standard curves that were used to calculate the size of the initial inoculum are shown in Figure 5.3.

Only one type of organism was inoculated onto a single drumstick in order to study their individual effect. Their growth patterns could easily be monitored by the appropriate selective media, but if both organisms were present large numbers and off-odours occurred it would be difficult to know which micro-organism was responsible. However, by studying the organisms individually, the effect of interactions between the two organisms would be unknown.

Figure 5.3. Optical density at 650nm of bacterial suspensions..





The Pseudomonas strain grew rapidly without a lag phase on the cling wrapped chicken drumsticks rising from 3.0 $\log_{10}$/g to more than 8.0 $\log_{10}$/g after 4 days (Table 5.15, Figure 5.4). The counts on PSM mirrored the TPC, which indicates that Pseudomonas dominated the population in the cling wrap samples. Even when numbers of Pseudomonas exceeded 10 $\log_{10}$/g no off-odours were detected. Therefore, this species of Pseudomonas must have been non-proteolytic, which was confirmed by the negative reaction to the gelatin liquefaction test on the API20E strip, which is indicative of proteolytic action. Shaw and Latty (1981) found that 82 isolates of non-fluorescent pseudomonads from meats contained a low incidence of strains producing extracellular enzymes.

In the absence of O_2 (vacuum packs) growth of Pseudomonas was reduced ten thousand fold. After 21 days of storage the PSM counts ranged between 1.08 - 8.57 x 10^6, which was one hundred fold less than the TPC, therefore suggesting that another organism was present. As this pattern developed prior to the end of storage, the vacuum packed samples were analysed on day 21 on MRS agar, which gave a count of 2.4 x 107/g, which suggests that Lactobacilli were the dominant species.

Where CO_2 was present the growth of Pseudomonas was inhibited and on days 4 and 7 the numbers of Pseudomonas were reduced to below 10^3/g.

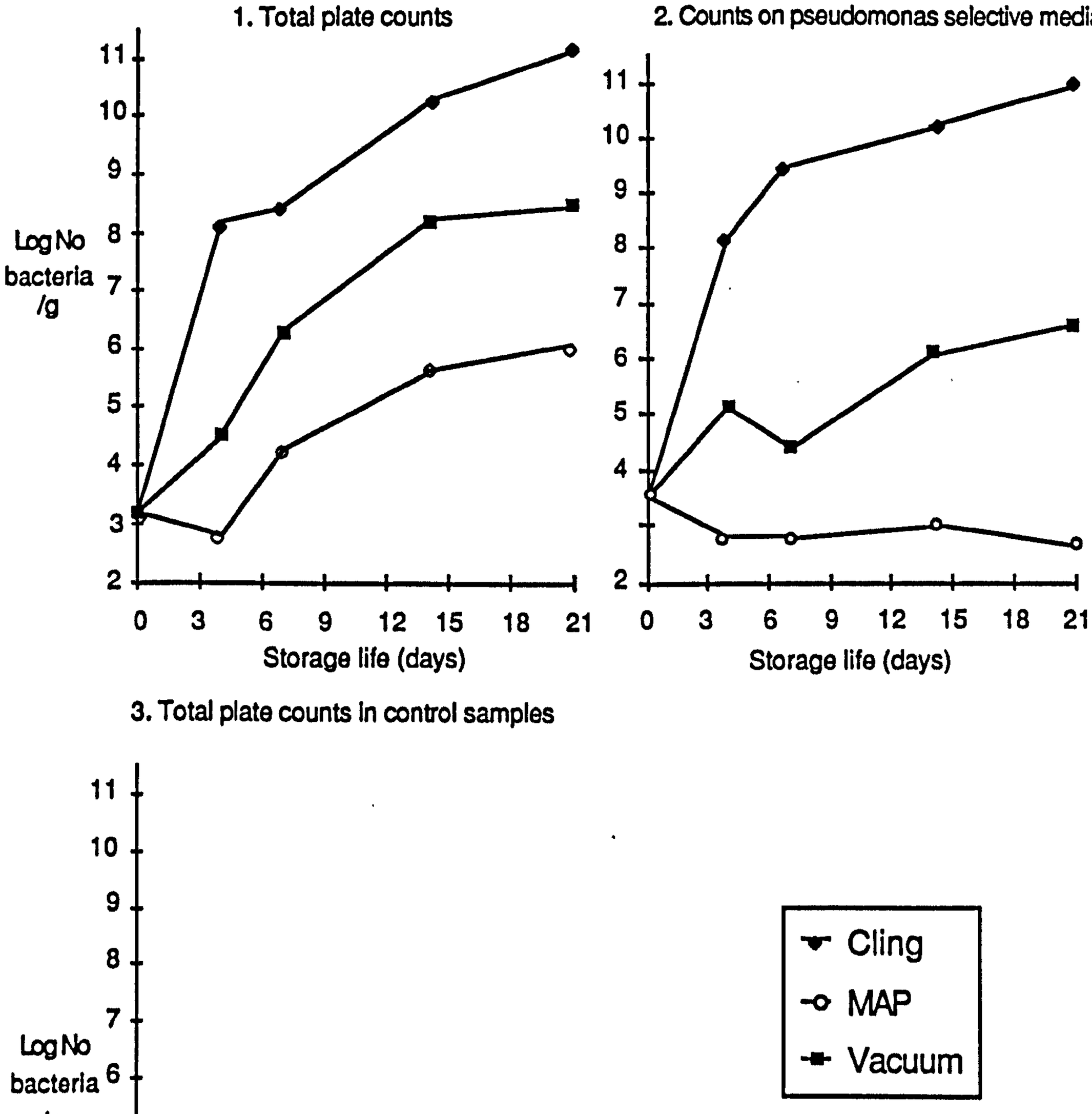
Table 5.15 The effect of packaging on bacterial counts* of chicken drumsticks inoculated with Pseudomonas and stored for 21 days at 4°C

*: mean of $\log_{10}$/g, 0 days n=6, other days n=4

Storage time (days)	Inoculated samples				Control samples	
	TPC		Pseudomonas (PSM)		TPC	
	Average	Range	Average	Range	Average	Range
After cooking and inoculation	3.22	3.08-3.73	3.54	3.42-3.88	<2.47	
Vacuum						
4	4.54	3.80-4.73	5.16	3.41-5.67	<2.47	
7	6.30	5.03-6.83	4.39	3.42-4.57	<2.47	
14	8.23	6.16-8.55	6.06	5.94-6.35	2.57	<2.47-2.57
21	8.42	8.28-8.52	6.65	6.03-6.93	<2.47	
MAP						
4	2.77	2.28-2.99	<2.80	<2.47-3.04	<2.47	
7	4.29	3.99-4.41	2.75	2.67-3.18	<2.47	
14	5.60	4.85-5.94	<3.01	<2.47-4.52	<2.47	
21	6.07	5.56-6.54	2.57	<2.47-2.73	<2.47	
Cling						
4	8.18	6.40-8.47	8.15	6.38-8.44	<2.47	
7	8.46	8.87-9.67	9.51	8.81-9.72	<2.47	
14	10.23	10.18-10.27	10.20	10.1-10.2	5.25	<2.47-5.71
21	11.11	11.01-11.22	10.93	10.8-11.0	2.73	<2.47-2.83

Figure 5.4. Bacterial counts* of chicken drumsticks inoculated with a Pseudomonas species

* mean $\log_{10}$ /g, n=4



On the drumsticks inoculated with Lactobacilli, the TPC were very similar to the counts on MRS agar on all packaging types indicating that the Lactobacilli were the dominant micro-organism throughout storage (Table 5.16, Figure 5.5). The growth rate of Lactobacilli was slower than that of Pseudomonas in air and the TPC at the end of storage were one hundred fold less. Thus, if the two organisms were present in the same numbers initially, Pseudomonas would be expected to dominate the population in the cling wrapped sample and Lactobacilli in the MAP and vacuum packed samples.

Growth was negligible in the uninoculated control samples, with the exception of the cling wrapped drumsticks on days 14 and 21. The strains responsible for this growth remain unidentified as growth on the selective media was negligible.

Table 5.16 The effect of packaging on bacterial counts* of chicken drumsticks inoculated with Lactobacilli and stored for 21 days at 4°C

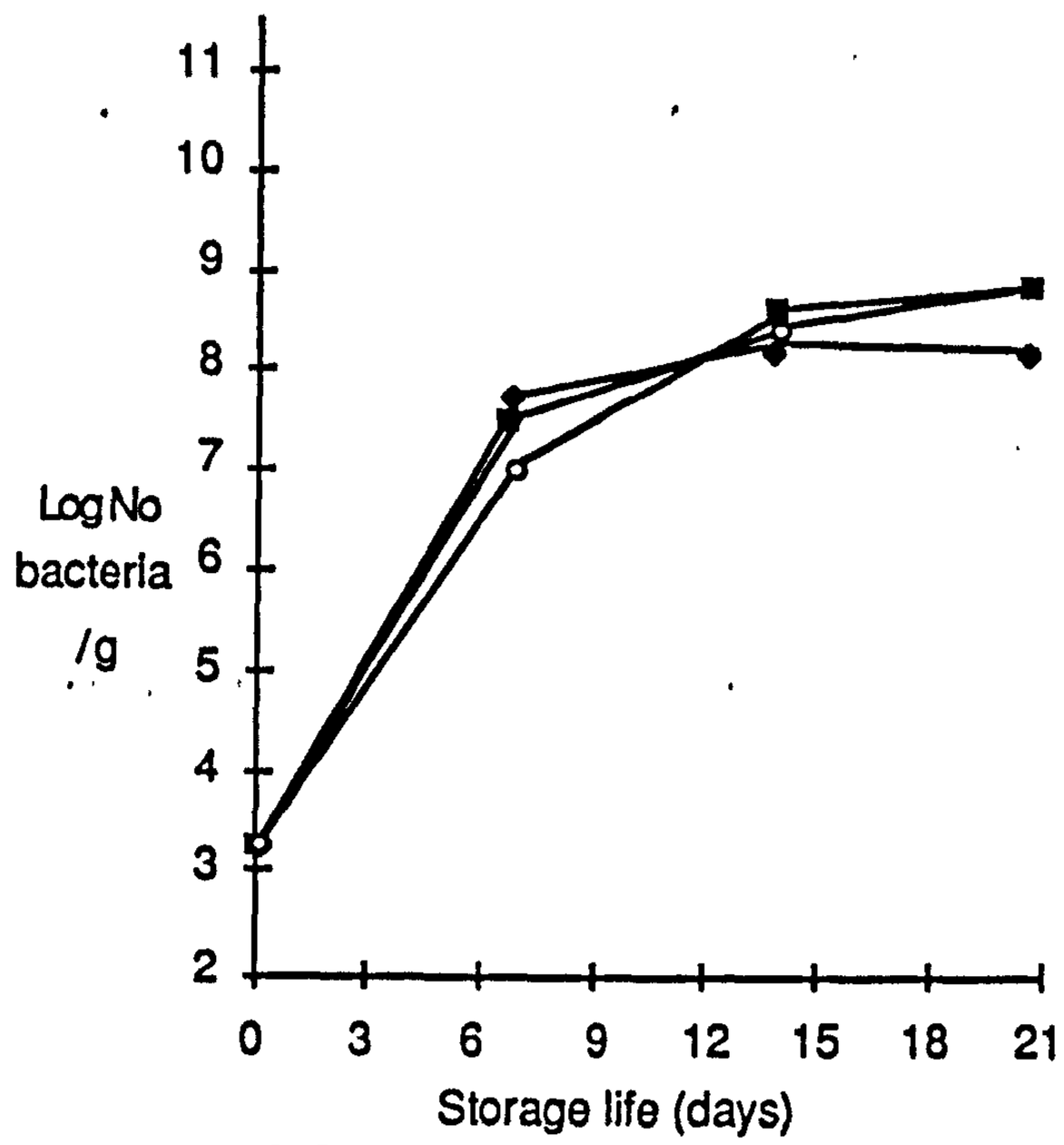
*: mean of $\log_{10}$/g, 0 days n=6, other days n=4

Storage time (days)	Inoculated samples				Control samples	
	TPC		Lactobacilli		TPC	
	Average	Range	Average	Range	Average	Range
After cooking and inoculation	3.22	3.08-3.73	3.54	3.42-3.88	<2.47	
Vacuum						
4	ND		5.35	3.15-5.94	<2.47	
7	7.56	7.36-7.76	7.64	7.38-7.97	<2.47	
14	8.42	8.38-8.46	8.82	7.76-8.98	<2.57	<2.47-2.57
21	8.84	8.67-8.99	8.80	8.67-8.93	<2.47	
MAP						
4	ND		5.43	4.69-5.93	<2.47	
7	7.12	6.60-6.87	7.13	6.54-7.37	<2.47	
14	8.59	8.24-8.84	8.52	6.89-8.73	<2.47	
21	8.84	7.68-9.16	8.88	7.92-8.76	<2.47	
Cling						
4	ND		5.58	5.39-5.83	<2.47	
7	7.75	6.72-8.16	7.78	6.81-8.18	<2.47	
14	8.28	7.97-8.48	8.48	5.38-8.88	5.25	<2.47-5.71
21	8.15	6.26-8.62	7.95	6.23-8.37	2.73	<2.47-2.83

ND: no data available

Figure 5.5 Bacterial counts* of chicken drumsticks inoculated with a species of Lactobacilli

*mean log10/g, n=4



Again no definite off-odours were detected on the drumsticks. In a study of vacuum packed sliced luncheon meats inoculated with Lactobacilli and Brochothrix thermosphacta, Egan et al., (1980) concluded that a count of 10^8/g did not mean the product was spoiled. Spoilage depended on the exact nature of the product under test, the strains of bacteria chosen, the conditions of storage and the judges expectations. Similarly Silla and Simonsen (1985) who examined the shelf-life of cured cooked meat products found that the end of shelf-life was not closely related to a certain bacterial count, whether measured on PCA, MRS or STAA. They concluded that bacterial limits were not valid unless combined with organoleptic criteria.

5.4. Conclusions

The development of the microflora in stored cooked foods is dependent on a variety of factors, some of which are of more concern to the caterer than others, as they exert a greater influence on microbial growth and also because they inhibit microbial growth without altering the product itself. Temperature and storage atmosphere are two such factors.

However, the combination of other factors inhibiting or stimulating microbial growth can be substantial as was shown in the current pilot experiments. Following which, the muscle type (reflecting differences in pH) and the initial level of microbial contamination were felt to be important and therefore standardized in subsequent experiments. After the first major experiment, it was clear that it was not enough to only standardize the initial numbers of micro-organisms, as their composition was of equal importance in influencing the developing microflora. It is well known that under aerobic conditions of storage Pseudomonads will dominate the population if present initially, whereas in anaerobic conditions Lactobacilli or Brochothrix thermosphacta are likely to be the dominant strains. However, if these species are not present in cooked foods other organisms will

predominate. The microflora of cooked foods consists of both heat resistant organisms which survive the cooking process and are likely to be heat damaged and unable to grow at chill temperatures and organisms present as a result of post cooking contamination. In practice, the composition of the microflora will be determined by the standards of hygiene and control employed in the kitchen. The microbiological data from previous studies of catering systems varies enormously, even when the differing nature of the foods are taken into consideration (Section 1.3). This is not surprising as standards of hygiene are not uniform throughout industry.

Despite these inherent problems of studying cooked foods it is vital to establish the effect of factors within the control of the caterer in order to allow the optimization of control systems. For example, the implementation of measures such as maintenance of cold storage temperature as close as possible to $0^{o}C$, and minimizing fluctuations in temperature and hygienic practices to achieve a consistently low level of product contamination. The interaction between factors affecting microbial shelf-life should be emphasized. As they act in combination, attention to all areas of control should be given.

Reducing temperatures had an inhibitory effect on microbial growth, especially in those products stored aerobically where Pseudomonas dominated the population. This was less obvious in some of the cling wrapped products however, so the temperature effect is clearly dependent on the growth characteristics and numbers of the species present. As those numbers are generally fewer than those found in raw food the effect of reducing temperature in inhibiting growth of spoilage bacteria is likely to be less with cooked foods than with raw foods. However, the main reason for lowering temperatures of storage is to reduce the risk of growth of food poisoning organisms (Chapter 4).

In the presence of a mixed microflora the inhibitory or stimulatory effect of modifying storage atmospheres may have

been masked. For this reason in the last experiment two micro-organisms were examined in isolation, the results of which clearly show how the effect of packaging is dependant on the type of bacteria present initially. However, if these two organisms are taken to be representative of common contaminants of cooked food, then microbial growth will be least in the MAP products, followed by vacuum packed products, and greatest in the cling wrapped products. This is because the growth of Lactobacilli in all packaging proceeds at a slower rate and tails off at a lower level than the growth of Pseudomonas.

CHAPTER 6

THE DEVELOPMENT AND ASSESSMENT OF TWO SENSORY PANELS TO EXAMINE THE EFFECT OF PACKAGING AND STORAGE LIFE ON THE SENSORY QUALITY OF COOKED MENU ITEMS.

6.1. Introduction

The organoleptic quality of a cooked food has been shown to alter within a very short time of cooking, whether it is held hot (Lundgren et al., 1979) or chilled and stored at refrigerator temperatures (Pokorny et al, 1982). The purpose of the sensory investigations in the present study was to determine the effect of packaging and storage time on the rate and type of organoleptic changes occurring in cooked menu items. This would enable the storage conditions that minimize loss of quality to be identified.

The investigation was divided into a pilot and a major study. The pilot study employed simple sensory methods that were able to establish whether actual differences between samples stored for varying lengths of time existed. Once their presence was demonstrated the major study examined the joint effect of packaging and storage life on sensory quality and also allowed these differences to be characterized and quantified and their inter-relationships determined.

This chapter presents the sensory methods employed in both experiments, the results of the pilot experiment and an assessment of the two taste panels used in the major experiment. The experimental design is also discussed in this chapter. The univariate and multivariate analysis of the results of the major sensory experiment are presented and discussed in Chapter 7.

Deep fried chicken drumsticks and chicken a la king for which the microbiological history had been assessed (see

Chapter 5) were chosen for analysis. Cooked chicken is especially vulnerable to pronounced flavour changes during refrigerated storage (Jacobson and Koehler, 1970; Harris and Lindsay, 1972; Pokorny et al., 1982; Dawson and Gartner, 1983), but little work has been undertaken on a composite chicken dish, such as chicken a la king, where the addition of other ingredients may have an effect on these changes.

In deciding upon the length of storage time, the following points were considered. The DHSS guidelines on cook-chill procedures recommend that foods should be stored for a maximum of five days at 3^{o}C after blast chilling. Thus, the shelf life of foods prepared in this way, is effectively restricted to five days and any quality deteriorations within this time are of particular significance.

The results of other investigations were examined. Jakobsson and Bengtsson (1972) found a significant deterioration in the flavour of cooked beef after only one day of refrigerated storage. Zallen et al. (1975) also found significant differences in quality characteristics of beef loaves stored for up to nine days at chill temperatures. In contrast, Bunch et al (1976) obtained overall acceptability scores for beef soy loaves, which were almost identical for 24, 48 and 72 hours of chilled storage. Neither of the latter two investigations indicate at what point the quality or acceptability of the products began to deteriorate.

The results of the microbiological investigations indicate that total plate counts (TPC) in chicken a la king do not approach 1 x 10^{6}/g , until after seven days storage at 4^{o}C and 17 days storage at 0^{o}C under cling wrap conditions. Under vacuum packaging, maximum cell numbers in chicken a la king, after 21 days storage at 4^{o}C were 5.0 x 10^{6}g. The TPC of chicken drumsticks were less than those of chicken a la king. It therefore appears, that significant microbial growth is unlikely, prior to six days for cling

wrapped chicken a la king and 15 days for whole drumsticks and 21 days for vacuum packed products.

On consideration of these factors, a storage time of 7 days for cling wrapped drumsticks and 14 days for vacuum packed drumsticks, were thought to be appropriate.

6.2. Methods

6.2.1. Methods used in the pilot experiment

Preparation of the cooked chicken is described in Appendix 2 and the chicken a la king in Chapter 2. Foods were wrapped in cling film and stored at $4^{o}C \pm 1^{o}C$ in a Foster refrigerator for 0, 2, 4 and 6 days.

6.2.1.1. Selection of judges

The screening and selection of judges was divided into two stages. Stage one involved two screening tests; (a) the identification of common substances by odour using the appropriate descriptive terms and (b) the detection of differences by taste between full strength and dilute strength chicken broth.

In the second stage of screening, subjects assigned scores to six samples of minced chicken (three freshly cooked samples (day 0) and three samples stored for six days) for the following attributes, appearance, odour, texture, flavour and overall acceptability. The same attributes were examined in the pilot experiment. Subjects were screened on the basis of ability to discriminate differences in samples and also ability to reproduce results.

The second stage of screening included some training, as the judges became familiarized with the laboratory situation and acquainted with the terminology to be used. Agreement was secured on the meaning of descriptive terms used.

The form used to evaluate the samples is shown in Appendix 4. The chicken salad and the appearance of the chicken a la king were evaluated on the cold products, but the other attributes of the chicken a la king were evaluated after reheating in a Sanyo microwave (Model EM-1800) for 30 seconds on full power. Light refreshments were served after each taste panel session. The experiment was replicated three times by 8 judges.

6.2.1.2. Analysis of results

Three way analysis of variance was used to determine the effect of days of storage, replications and judges. Multiple regression analysis was used to identify the sensory attributes affecting quality and Pearsons parametric correlation coefficients were calculated between acceptability and other quality attributes (Snedecor and Cochran, 1967).

6.2.2. Major experiment

6.2.2.1 Preparation and storage of samples

Preparation and packing of the chicken drumsticks is described in Chapter 2. Samples were stored in a Rowe 448 vending machine, the temperature of which was monitored throughout the experiment by a Grant miniature time temperature recorder. Slight temperature fluctuations occurred between the top and bottom of the cabinet and so each judge received their samples from the same shelf of the drum vendor, thus eliminating variations in storage temperatures within a single judges samples.

6.2.2.2. Methods of screening, selection and training of judges

Sensory evaluation was by means of quantitative descriptive analysis (Stone et al., 1974 & 1980; ASTM, 1968;

BSI, 1980). Prospective judges were students or staff at the Dorset Institute of Higher Education, all of whom were unpaid volunteers. Requests for volunteers were made during a short introductory talk about the project and the sensory experiments. Handouts explaining the commitment and work involved were dispersed, together with a questionnaire to be completed by volunteers. The objective of the latter was to gain information about the age, sex, smoking habits, food dislikes, relevant medical conditions (ulcers, sinus problems and allergies) and the time available of the volunteers.

The following tests were used during the screening procedures:

1. Recognition of the four basic tastes: sweet (sucrose), salt (sodium chloride), bitter (caffeine) and sour (tartaric acid) (Amerine et al., 1965).

2. Arrangement of four solutions of sucrose (0.3-1.2%), in order of strength.

3. Recognition of five commonly encountered food odours; vinegar, vanilla, peppermint, almond and onion.

4. Recognition of four less common odours, chosen at random from a choice of 54 odours (Le Nez du Vin, Jean-Jaques Figeac, 86-89 Garratt Lane, London SW18).

Selected panellists successfully completed the first three tests. Points noted on the questionnaire and other aspects of the sensory analysis were discussed with each volunteer individually, in order to encourage and assess their motivation and to discourage those volunteers with medical conditions or habits that affect their olfactory organs and those who disliked the foods under investigation.

Successful volunteers went on to take part in the training programme, which consisted of eight 45 minute

sessions. During the first session, the objectives of the training were explained together with an introduction to scoring methods, questionnaires and terms commonly used in sensory analysis. Instructions were given on methods of standardizing testing procedures. Panel members undertook a triangle test of chicken stock dilutions and the scoring of two chicken drumsticks (day 0 and stored for 6 days) for odour, juiciness and flavour.

Sessions 2-5 involved the identification of the important sensory attributes of the different samples. Each session dealt with either appearance, odour, juiciness or flavour. Each panel member independently examined samples and recorded their findings, followed by a group session for reporting and discussion of individual findings. Language difficulties and disputed points were resolved and ideas were exchanged. A sensory profile of the perceived characteristics of the product was established and a questionnaire was formed. At the end of the training session the panel members individually rated the perceived characteristics of unidentified samples labelled with three figure random numbers. Evaluations were made by placing a vertical mark across an unstructured line 15 cm long and anchored at either ends by pairs of terms. The score sheets used in the actual experiments are shown in Appendix 5.

During the last three sessions it was ensured that the range of sample treatments to be encountered in the actual experiment had been examined and that all panel members clearly understood the terms used to define the perceived characteristics.

6.2.2.3 Experimental design and statistical analysis

The experimental design incorporated a split plot design with sub unit treatments in latin squares (Cochran and Cox, 1957) (Table 6.1. and Section 6.5). Factor A or the whole units consisted of packaging (cling:C, vacuum:V and CO_2:A), factor B or the sub units consisted of age (0, 4, 7, 11 and

14 days)and factor C consisted of the subjects (eight evaluated the chicken drumsticks and six evaluated the chicken a la king). The position of the three packaging types were randomly allocated in each replication.

A problem arose when the sub-unit treatments were arranged in latin squares, as for the cling wrapped products there were only three levels of age and for MAP and vacuum packed products there are five levels of age. For this reason it was decided to use two 3x3 latin squares for the cling products and one 5x5 latin square for both the MAP and vacuum products. The latin squares were randomized and the first column of each square was assigned to the first replication of the experiment. The whole design was repeated for each subject as shown in Table 6. Thus, each column of the latin square determined the order of presentation to the subjects. One block of 5 or 3 samples was presented at once and at any one session subjects would examine no more than two blocks.

Table 6.1 A split plot design with sub-units (product age) in latin squares
(repeated for each subject; sub-sub-units).

	WHOLE UNITS (Packaging)		
Replications	MAP	Vacuum	Cling
(1)			
SUB	0	7	4
UNITS	14	11	7
(Storage life,	4	14	0
in days)	7	0	
	11	4	

(2)	Vacuum	MAP	Cling
	0	14	7
	14	11	0
	4	0	4
	7	4	
	11	7	

(3)	Vacuum	Cling	MAP
	14	0	7
	4	4	4
	0	7	11
	11		0
	7		14

(4)	MAP	Cling	Vacuum
	4	0	4
	7	4	7
	14	7	11
	11		14
	0		0

(5)	Vacuum	MAP	Cling
	11	11	7
	0	0	0
	7	7	4
	4	14	
	14	4	

(6)	Cling
	4
	7
	0

6.2.2.3.1 Univariate statistical analysis

Before statistical evaluation, all judgments were transformed into scores by placing a ruler against the 15 cm line. The scores for each attribute were analyzed separately. Because of the varying numbers of levels of storage life (cling - 3 age levels; MAP and vacuum - 5 age levels) two separate models for each menu item for three way analysis of variance (ANOVA) were used, according to pack, storage life and judge. The difference between them being the number of age and packaging treatments. The basic models for each menu item and breakdown of degrees of freedom are shown in Table 6.2. Where significant interaction effects occurred between replications and storage life or pack and storage life, their sums of squares were included in calculating the error term with which the F value for storage life was calculated. The distribution of F, like chi squared and t is one of the basic distributions in modern statistical methods and is used to test the equality of variances. The test criterion or F value is the ratio of the two mean squares ($F = s_1^2 / s_2^2$, where s_1^2 is the larger mean square) (Snedecor and Cochran, 1967). Where significant differences were found ($P < 0.05$) among mean scores for storage time (age) and pack, differences among samples were determined by the method of least significant differences (LSD). Where thought helpful in the interpretation of results confidence limits on the estimated effects were calculated (Snedecor and Cochran, 1967).

Table 6.2 The three way ANOVA model used to analyse the split plot design.

$$Y_{ijkl} = u + R_i + P_j + RP_{ij} + S_k + RS_{ik} + PS_{jk} + RPS_{ijk} + T_l + RT_{il} + ST_{jl} + RPT_{ijl} + ST_{kl} + RSTikl + PST_{jkl} + RPST_{ijkl}$$

Effects:

			Number of levels			
			Chicken drumsticks		Chicken a la king	
			Model 1	Model 2	Model 1	Model 2
R:	Replications	i	5	5	5	5
P:	Packaging	j	3	2	3	2
S:	Storage life	k	3	5	3	5
T:	Judge	l	8	8	6	6

Breakdown of degrees of freedom:

Effect	Chicken drumsticks		Chicken a la king	
	Model 1	Model 2	Model 1	Model 2
Whole plot				
R	4	4	4	4
P	2	1	2	1
PR (error a)	8	4	8	4
Split plot				
S	2	4	2	4
RS	8	16	8	16
PS	4	4	4	4
RPS (error b)	16	16	16	16
Split split plot				
T	7	7	5	5
RT	28	28	20	20
PT	14	7	10	10
ST	14	28	10	20
Error c	252	280	180	195
Total	359	399	269	299

ANOVA was also undertaken on sub-sets of the data in order to examine in detail the individual subjects ability to reproduce results and their use of attribute descriptive terms as descriminators of sample differences.

6.2.2.3.2. Multi variate analysis

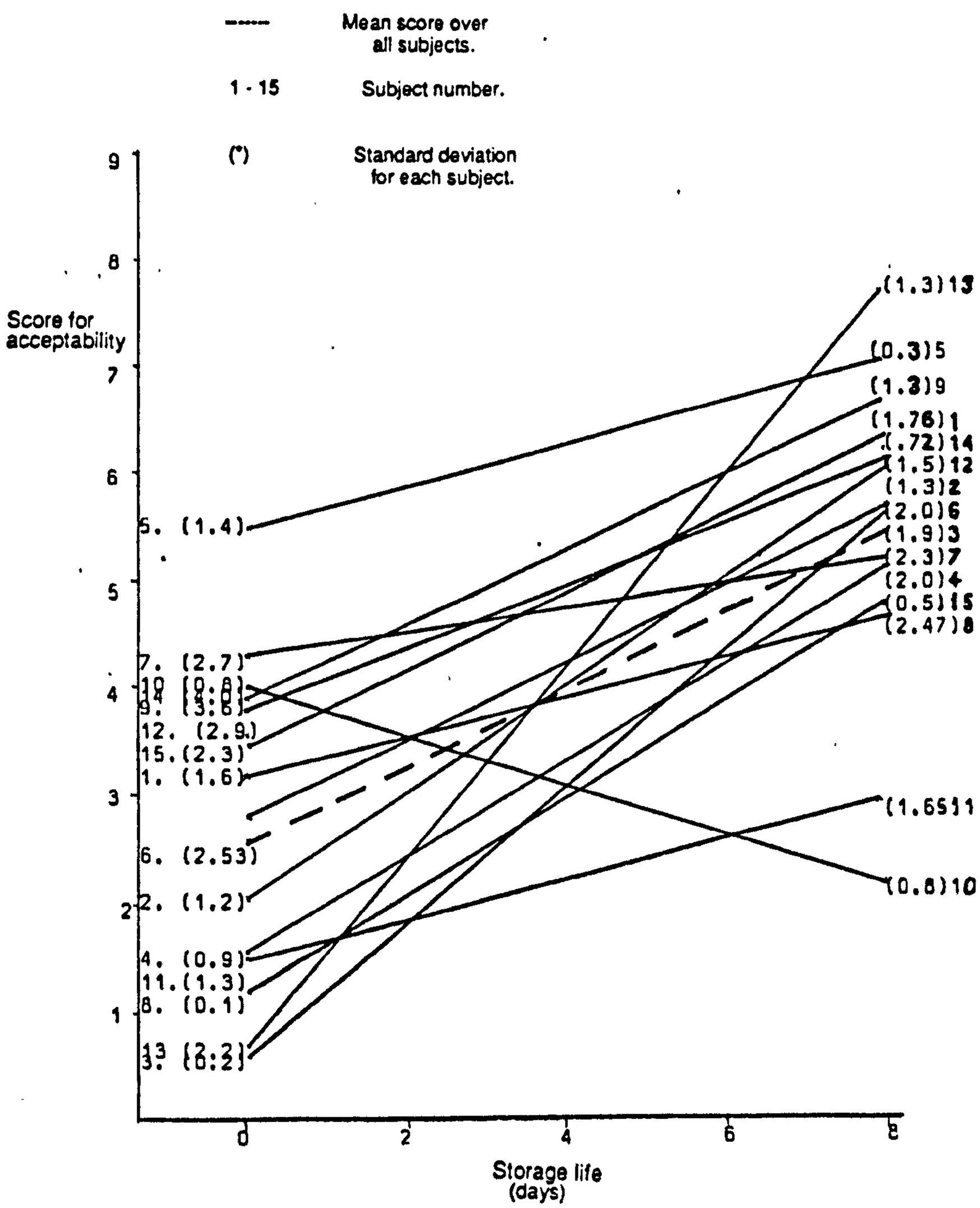
The data for all the attributes was combined in the following multivariate analyses; factor analysis (principal

component analysis), stepwise discriminant analysis and cannonical correlation analysis. The SPSS system was used and the individual data scores were used as input.

6.3. Results and discussion: pilot experiment

From a total of 23 volunteers, 15 were accepted for the second screening stage. Judges mean scores of the samples presented during the second screening stage, were plotted on a graph to compare their individual mean scores with other judges scores and also the overall mean score of the group. An example is shown in Figure 6.1. This indicates which panel members deviate most from the average of the group, i.e. those who score the older product more highly and those unable to distinguish any differences between the sample treatments (high standard deviation).

Figure 6.1 Scores of individual judges for the acceptability of minced chicken in the pilot sensory experiment (n=3)



Eight panellists were selected to take part in the actual experiment. The reproducibility of the judges scores were analyzed for each individual and for the mean score for the whole group. The group mean score was consistent for all attributes except the odour and juiciness of the chicken portions (Table 6.3). The individuals were able to reproduce their scores for appearance and acceptability, but some were unable to reproduce their scores for odour, juiciness and flavour. Acceptability is strongly related to personal preferences, which do not tend to alter within a short time period, whereas an individuals perception of the degree of a particular attribute such as flavour may change, particularly in the absence of standards with which to anchor their judgements. In addition, flavour, odour and texture are complex attributes and may not have been adequately defined. Training is intended to counteract any drift in the use of scales and ensure subjects understand fully the descriptive terms, consequently additional training was incorporated into the major experiment.

Table 6.3 The three way analysis of variance of sensory scores of cooked chicken items, stored in a refrigerator for six days (F values) (Pilot experiment).

Attribute	Days of storage	Repli -cations	Judges	Interaction Days x reps.	Days x judges	Reps.x judges
CHICKEN PORTIONS						
Appearance	*6.89d	0.63	3.56d	2.03	0.5	0.93
Odour	33.64d	3.23d	2.6 d	2.36d	3.83d	2.05d
Juiciness	9.43d	3.59d	1.58	1.68	1.85d	2.12d
Flavour	33.8 d	1.2	5.27d	1.32	3.81d	1.13
Acceptability	36.79d	0.44	1.11	0.66	0.9	1.41
CHICKEN A LA KING						
Appearance	1.74	1.9	3.43d	0.86	1.17	1.0
Odour	1.23	2.64	5.7 d	1.75	1.77	1.4
Juiciness	13.12d	0.06	2.84d	0.04	1.17	0.96
Flavour	3.76d	0.70	0.77	0.83	0.65	0.48
Acceptability	3.01d	0.17	2.79d	0.8	0.63	0.83

d : significant at the 5% level

There was significant interaction between the days of storage and the judges, which indicates that the effect of the days of storage was dependent on the particular judge. Where judges were able to reproduce scores throughout the study, differences between judges could be attributed to different uses of the scales, which should not have interfered with determining the effect of storage life. Where interaction is between days and replications or replications and judges and or where there is a significant difference between replications, results are more difficult to interpret.

During the six days storage in the refrigerator, the appearance and odour of the chicken a la king did not significantly differ, whereas flavour, juiciness and acceptability did differ ($P< 0.05$). All the measured attributes of the chicken portions differed significantly ($P<0.05$) over the six days storage period in the refrigerator.

The results for the regression analysis relating the attributes with acceptability are shown in Table 6.4. The attributes most affecting the acceptability of chicken portions were appearance and flavour, as they had the steepest slopes and highest correlation coefficients. For chicken a la king stored in the refrigerator, the flavour of the product was by far the most important attribute.

Table 6.4 Regression analysis* of acceptability scores and scores for other attributes (flavour, juiciness, odour and appearance).

*: Acceptability score= a + (b x attribute score)

	Intercept (a)	Slope (b)	Pearsons parametric correlation coefficient
Refrigerated chicken drumsticks			
Appearance	0.95	0.81	0.74
Flavour	0.71	0.82	0.69
Juiciness	1.29	0.59	0.50
Odour	0.75	0.71	0.65
Refrigerated chicken a la king			
Appearance	2.06	0.51	0.45
Odour	1.91	0.44	0.40
Juiciness	1.89	0.54	0.51
Flavour	-0.06	0.96	0.77

It is apparent that significant changes occur during the chilled storage of chicken products, however, the sensory analysis was such, that a more detailed investigation was required to highlight the precise nature and degree of changes and also the effect of packaging.

6.4. Assessment of the taste panels employed in the major experiment.

Small trained sensory panels produce far less variation in replicated judgments than large untrained panels and are therefore frequently used for measuring differences between samples (Amerine et al., 1965). Two separate panels were used in the study, due to the large volume of work involved and the voluntary nature of the sensory panel.

A total of 15 students volunteered and successfully completed the screening tests for the chicken drumstick training programme, during which attendance dwindled leaving a core of 8 judges who participated in the actual experiment. The final panel for evaluating the chicken a la king consisted of 6 judges, from a total of 12 volunteers. The descriptions of the sensory attributes of the two menu items selected by the two sensory panels are shown in Table 6.5.

Table 6.5. The attribute descriptive terms selected by judges for each product

Sensory attribute	Descriptive term	
	Low score	High score
Chicken drumsticks		
APPEARANCE		
Shrivelled	No shrivelling	Very shrivelled
Brightness	Not bright	Very bright
Dry appearance of flesh	Not Dry	Very dry
Compact appearance of flesh	Moderately compact	Very compact
ODOUR		
Natural fried chicken odour	Weak	Strong
Rancid odour	Absent	Strong
Bland odour	Weak	Strong
TEXTURE		
Juiciness of flesh	Not juicy	Very juicy
Degree of chewing	Low	High
First bite	Less resistant	More resistant
FLAVOUR		
Fresh fried chicken flavour	Weak	Strong
Rancid flavour	Weak	Strong
Bland flavour	Weak	Strong
Chicken a la king		
APPEARANCE		
Sauce:		
Granular/pastey	Absent	Present
Gelatinous texture	Not set	Well set
Depth of colour	Weak	Full
Sauces coating properties (peas/pimentos)		
	No coating	Coats well
Appearance of meat	Broken up	Whole
Shade of pea colour	Fresh pea colour	olive khaki
Pea colour range	Not variable	Variable
Samples returned for reheating		
Surface oil on reheated sample	Absent	Present
ODOUR		
Sauce odour	Fresh	Stale
Depth of chicken odour	Weak	Strong
TEXTURE		
Sauce texture	Coarse	Smooth
Meat texture	Breaks down readily	Chewy
Variability of pea texture	Not variable	Variable
FLAVOUR		
Staleness	Absent	Present
Acidic flavour	Absent	Present
Degree of sweetness	Weak	Strong
Degree of saltiness	Weak	Strong
Chicken flavour of meat	B	

6.4.1. Evaluation of individual judges performance

Individual subjects F values (one way ANOVA for replications) for each attribute of chicken drumsticks and chicken a la king are given in Appendix 5. Where the F values are significant ($P<0.05$) the subject was inconsistent in scoring that attribute. To simplify the interpretation of these results the total number of significant F values for each subject is given in Table 6.6 and the sum of individual subjects F values and rank order in Table 6.7. The more consistent judges were expected to have a low sum of F values.

Table 6.6 The number of significant ($p<0.05$) replication F values for each judge.

Subject	Packaging type			
	Vacuum	MAP	Cling	Total
Chicken drumsticks				
1	2	2	3	7
2	-	-	-	-
3	1	6	2	9
4	2	-	-	2
5	6	4	2	12
6	-	-	-	-
7	-	-	-	-
8	-	1	-	1
Chicken a la king				
1	2	3	4	9
2	1	4	3	8
3	-	1	-	1
4	5	2	3	10
5	6	2	-	8

Table 6.7. The sum of F values for each judge in rank order.

Rank	Packaging type: Vacuum	MAP	Cling
Chicken drumsticks			
1	7.08 (7)	5.35 (2)	5.32 (7)
2	8.82 (2)	8.62 (6)	8.08 (2)
3	11.19 (6)	10.58 (7)	8.12 (8)
4	12.11 (8)	13.92 (4)	10.95 (4)
5	13.73 (3)	15.09 (8)	12.49 (6)
6	18.94 (4)	19.44 (1)	15.51 (3)
7	24.95 (1)	31.43 (5)	21.45 (1)
8	51.44 (5)	44.58 (3)	22.40 (5)
Chicken a la king			
1	20.36 (3)	20.09 (3)	21.87 (3)
2	22.03 (2)	30.08 (4)	26.6 (5)
3	32.58 (4)	32.69 (1)	33.46 (1)
4	36.89 (1)	34.92 (2)	38.15 (2)
5	42.9 (5)	35.13 (5)	40.49 (4)

Numbers in parentheses correspond to the number of each judge.

6.4.1.1 Consistency in scoring chicken drumsticks

Judges number 2, 6 and 7 of the chicken drumsticks had no significant F values and low totals for summed F values and were therefore the most consistent judges throughout the experiment.

Judges 8 and 4 were the next most consistent judges with one and two significant F values respectively. They were not able to distinguish differences between samples using these attributes.

Judges 1, 3 and 5 were poorer at scoring consistently. Judges 3 and 5 appeared to have greater difficulty in consistently scoring the MAP and vacuum packed drumsticks than the cling wrapped drumsticks (Table 6.6).

The attribute that was most difficult for individual judges to score consistently was bland odour as it had the

most significant F values for replication (Appendices 6 and 7). The degree of chewing and rancid odour also caused difficulties in consistent judgments.

In the three way ANOVA models of chicken drumsticks, which took all the judges scores into consideration, differences between replications were significant for three attributes on model 1; dry appearance of flesh, juiciness of flesh and first bite. In model 2 the replication effect was not significant for any attribute. Where judges were not consistent in their scoring the significance of the main effects had to be recalculated by combining the replication sum of squares with the error term sum of squares. If the difference between the main effects was sufficient then significance would still be achieved (Chapter 7, Sections 7.2. and 7.3.).

6.4.1.2. Consistency in scoring chicken a la king.

Judge 3 of the chicken a la king was the most consistent scorer (Table 6.6), with only one significant F value and the lowest total for summed replication F values. The other four judges were similar in their reproducibility of results. As with the chicken drumsticks most judges were more consistent in scoring cling wrapped chicken a la king than the MAP or vacuum packed samples. This is particularly apparent with judge 5 (Table 6.6) where the results show this person to be the poorest at consistently judging MAP and vacuum packed samples but next to the best at judging cling wrapped samples.

Acidic flavour and chicken flavour were the most difficult sensory attributes for the subjects to score consistently.

Judges of the chicken a la king had to score 18 attributes as compared to the 13 attributes of the chicken drumsticks, therefore a larger number of significant F values

for replication were to be expected. The percentage of total replication F values that were significant and therefore represented inconsistent scoring were 13.3% for the chicken a la king and 10% for the chicken drumsticks, therefore the two panels did not widely differ in their reproducibility of results.

It was decided not to discard any judges scores as no judge was consistently poor in scoring all attributes and therefore discarding any judges data would result in an overall loss of information. However, in later analyses the effects of modifying data sets by removing some judges scores that were known to be inconsistent over replications or with the rest of the panel were examined.

6.4.1.3. Judges ability to use the attribute descriptive terms as discriminators.

The ability of judges to discriminate between storage life of samples by scoring the descriptive terms was indicated by the number of their individual significant F values for storage life which are listed in Appendices 6 and 7. Each subjects total number of significant F values for storage life is shown in Table 6.8.

Table 6.8. The number of significant F values for storage life ($p<0.05$) for each judge (one way ANOVA for storage life).

Judge	Packaging type: Vacuum	MAP	Cling	Total
Chicken drumsticks				
1	1	7	3	11
2	11	9	13	33
3	8	3	8	19
4	10	9	9	28
5	3	4	8	15
6	9	6	4	19
7	8	9	9	26
8	5	6	10	21
Chicken a la king				
1	1	1	4	6
2	4	2	4	10
3	3	4	5	12
4	1	6	1	8
5	6	3	2	11

Judges 2, 4, 7, and 8 of the chicken drumsticks had the largest number of significant F values for age (Table 6.8) and were therefore the best at discriminating differences. Judges 2, 4 and 7 discriminated equally well for all packaging types, whereas judge 8 was noticeably worse at discriminating differences in vacuum and MAP products as compared to cling wrapped products. Judges 3 and 6 were the next best at discriminating, but it should be noted that judge 3 was also relatively inconsistent at reproducing results (Tables 6.6 and 6.7). The ability of judge 5 to reproduce results was poor (Table 6.6 and 6.7), as was their ability to discriminate differences relative to the rest of the panel.

Judge 5 of the chicken a la king was noticeably better at distinguishing between the storage life of vacuum packed as compared to MAP or cling wrapped samples. Judge 4 was noticeably better at scoring MAP samples and judge 1 was best at scoring cling wrapped samples.

Judges of the chicken a la king found fewer differences between samples than judges of chicken drumsticks. For chicken a la king only 17% of all possible individual F values for storage life were significant ($P<0.05$), as compared to 55% for the chicken drumsticks. This confirmed the results of the pilot experiment (Table 6.3) and could be attributed to either the use of inappropriate discriminating terms for the chicken a la king or the inability of judges to discriminate differences in certain sensory attributes or a reduced effect of storage life on sensory quality.

6.5. Experimental design in the major experiment

The experimental design around which the three way ANOVA was modelled attempted to eliminate objective error due to the presentation sequence of the samples (position bias) by presenting each set of samples according to columns of a latin square (Table 6.1). According to Sidel and Stone (1976) random plans in sensory analysis may introduce considerable order bias as related to an individual judge, sample or period of time. In contrast, in a latin square all samples occur in all test positions an equal number of times. Objective error resulting from the time period elapsing between the examination of different samples was eliminated or reduced by using a split plot design (Table 6.1) (Snedecor and Cochran, 1967) and always including a day 0 sample to act as a standard.

The average experimental error over all treatment comparisons is the same for split plot designs as randomized block designs, therefore there is no net gain in precision in using a split plot design. However, an increase in precision of the second factor (storage life) and interaction between storage life and packaging was obtained by the sacrifice in precision of packaging (the number of degrees of freedom is less for whole unit comparisons than sub-unit comparisons). Five replications enabled the response consistency of the

panel and individual judges to be evaluated. Replications also allowed the magnitude of the experimental error to be estimated. Stone et al., (1974) suggested as many as 16 replications were necessary for quantitative descriptive analysis, but reduced this to a minimum of 4 in a later publication (Stone et al., 1980).

Training the judges and conducting the experiment under controlled conditions aimed to eliminate the subjective error due to differences between what the judges perceived to be the qualities of the product and what they actually were.

The use of parametric tests such as ANOVA depends on certain assumptions; normal or gaussian distributions of data; equal interval scales and also equal variances (homoscedascity). According to O'Mahoney (1982) it is doubtful whether these assumptions hold for sensory data. However, the panel composition was constant and therefore differences in central tendency between judges were eliminated. Also, even though the original sensory data was probably not normal, central limits theorem suggests that panel means might be closer to normal (CFPRA, 1983).

Schiffman et al., (1981) recommended the use of an undifferentiated line scale rather than a scale structured with numbers or descriptive terms, because people lose sight of the task at hand while they debate the meanings of 'somewhat' or 'fairly'. Also many subjects feel uncomfortable with segmenting the line with words.

6.6. Conclusions

The pilot sensory experiment indicated that the sensory attributes of both chicken a la king and chicken drumsticks refrigerated for 6 days significantly differed from the fresh unstored products. The type and degree of these organoleptic changes would be determined in the major experiment.

Significant differences also occurred between judges for several attributes and also in the scoring of two of the chicken drumstick attributes between replications. Such deviations in the performance of judges were considered undesirable and so training was introduced into the initial stages of the major experiment in order to improve the performance of the panels.

In the major experiment the two panels were both able to satisfactorily reproduce their results. Their ability to discriminate between samples by using the descriptive terms selected during the training sessions varied, but all judges contributed to differentiation on at least 4 descriptive terms. In addition to reducing subjective error by training the panel, objective error caused by presentation bias and time elapsing between tasting sessions were minimized by the experimental design.

CHAPTER 7

THE ANALYSIS OF THE EFFECT OF PACKAGING AND STORAGE LIFE ON THE SENSORY QUALITY OF CHICKEN DRUMSTICKS AND CHICKEN A LA KING

7.1. Introduction

The results of the univariate analyses are presented in the first half of this chapter and the results of the multivariate analyses are presented in the second half.

7.2. Univariate analysis of chicken drumsticks

Following the examination of the performance of judges, the effect of storage life and packaging on the attributes outlined in Table 6.3 were determined by means of three way ANOVA. The complete ANOVA Tables for each attribute and model are given in Appendix 7 and a summary of the F values for each sensory attribute of chicken drumsticks in Table 7.1. The mean scores for each sample and attribute are presented in Table 7.2.

Table 7.1 F values for three way ANOVA of chicken drumsticks

	Degree of shrivel -ling	Bright -ness	Dry appear -ance	Compact appear -ance	Fried chicken odour	Rancid odour
Model 1, 3 levels of packaging, 3 levels of storage life, 8 judgements and 5 replications of study.						
Whole plots						
R	2.37	2.25	5.80b	1.04	0.44	1.06
P	11.59c	1.54	0.42	.90	2.05	10.09c
Split plot						
S	9.71c(1)	27.10d	66.91d	47.37d	150.15d	25.38d (2)
RS	2.11	3.37	2.63b	2.27	1.76	0.99
PS	3.82b	1.64	1.42	1.46	3.18	8.13d
Split split plot						
T	2.41b	2.01	0.63	0.96	0.81	1.22
RT	0.01	0.18	0.16	0.18	0.35	0.45
PT	0.25	0.06	0.18	0.04	0.11	0.84
ST	1.64	1.65	0.57	0.86	0.87	1.02

	Bland odour	Juiciness of flesh	Chewing	First bite	Fried chicken flavour	Rancid flavour	Bland flavour
Model 1, 3 levels of packaging, 3 levels of storage life, 8 judgements and 5 replications of study.							
Whole plots							
R	1.30	3.99a(5)	2.95	7.52c	1.70	2.52	0.20
P	5.34c	7.19b	5.05	6.93b(3)	1.18	12.73b	5.06a
Split plot							
S	35.18d	99.00d(6)	58.66d	112.61d(4)	230.05d	25.93d	58.86
RS	1.22	1.32	2.29	4.45c	1.47	1.58	0.64
PS	2.57	3.74b	2.89	5.85c	0.84	10.36d	3.69
Split split plot							
T	2.38	1.15	1.07	1.61	0.64	4.08d	2.81c
RT	0.44	0.11	0.14	0.16	0.24	0.52	0.46
PT	0.44	0.12	0.12	0.14	0.21	1.09	0.40
ST	1.68	1.03	0.87	1.13	0.97	2.71c	2.03

a: P<0.05
b: P<0.025
c: P<0.01
d: P<0.001

R: replications
P: packaging
S: storage life
T: judge

Recalculated F values for pack and storage life when significant interaction effects are combined in error terms:
(1) F value for storage life= 6.21 P<0.025
(2) F value for storage life=10.45 P<0.01
(3) F value for pack=2.18 P>0.05
(4) F value for storage life=42.02 P<0.01
(5) F value for pack=3.60 P>0.05
(6) F value for storage life=63.94 P<0.001

Table 7.1 (continued)

	Degree of shrivel -ling	Bright -ness	Dry appear -ance	Compact appear -ance	Fried chicken odour	Rancid odour
Model 2, 2 levels of packaging, 5 levels of storage life, 8 judgements and 5 replications of study.						
Whole plots						
R	0.85	2.19	1.43	0.28	0.05	0.48
P	43.38c	8.97a	0.22	3.02	1.21	0.73
Split plot						
S	2.37	36.57c(2)	34.68c	36.49c	249.26d(1)	30.30c
RS	1.38	3.81c	1.10b	1.76	2.88a	0.64
PS	3.26a	1.96	1.31	1.44	1.90	1.18
Split split plot						
T	2.07a	1.77	0.54	0.92	2.75c	2.84c
RT	0.80	0.22	0.29	0.04	0.17	0.37
PT	0.39	0.42	0.20	0.20	0.39	0.58
ST	0.38	0.29	0.17	0.15	0.52	0.57

	Bland odour	Juiciness of flesh	Chewing	First bite	Fried chicken flavour	Rancid flavour	Bland flavour
Model 2, 2 levels of packaging, 5 levels of storage life, 8 judgements and 5 replications of study.							
Whole plots							
R	3.46	2.30	1.07	0.61	0.58	1.56	0.39
P	1.27	12.67a	2.04	3.14	0.06	5.01	0.56
Split plot							
S	14.86c	72.93c	79.15c(3)	24.16c	207.94d	22.01c	48.27
RS	1.28	0.87	4.22a	1.05	1.26	0.37	1.84
PS	1.07	2.38	1.65	1.18	0.89	1.09	2.48
Split split plot							
T	2.65	1.59	1.49	2.17	2.48a	5.83c	1.79
RT	0.19	6.49c	0.11	0.26	0.07	0.29	0.28
PT	0.27	0.34	0.22	0.27	0.59	0.55	3.18c
ST	0.58	0.24	0.21	0.26	0.29	0.49c	0.45

a: $P<0.05$
b: $P<0.025$
c: $P<0.01$
d: $P<0.001$

Recalculated F values for pack and storage life when significant interaction effects are combined in error terms:

(1) F value for storage life= 129.38 $P<0.001$
(2) F value for storage life= 15.18 $P<0.01$
(3) F value for storage life= 30.32 $P<0.01$

The results are discussed in detail in the next section but will be briefly summarized here. All sensory attributes were significantly ($P<0.05$) affected by storage life, with the greatest effect occurring between 0 and 4 days of storage. The fried chicken flavour and odour scores were the attributes most influenced by storage time, showing large losses with increased storage. The appearance of the cling wrapped chicken drumsticks was significantly ($P<0.05$) more shrivelled and drier and they developed more rancid odours and flavours ($P<0.05$) than the MAP or vacuum packed samples. In comparison with the other packaging types, vacuum packed drumsticks were more resistant on first bite, required more chewing and were less juicy. When comparing packaging types for a given age, the scores for the MAP drumsticks tended to be the closest to the fresh sample scores and the cling wrapped samples the furthest.

Table 7.2 Mean scores* for sensory evaluation of chicken drumsticks given as different packaging treatments presented as days within packaging types.

* 8 judgements, 5 replications of study and scale of 0 to 15.

Pack	Age (in days)	Degree of shrivel -ling	Bright -ness	Dry appear -ance	Compact appear -ance	Fried chicken odour	Rancid odour
Vacuum	0	2.97a	4.94a	1.35a	2.11a	6.23a	.54a
	4	2.34b	2.76b	4.34b	4.17b	2.39b	1.99b
	7	2.53b	3.26b	4.17b	4.94c	2.29b	2.49b
	11	2.25b	2.47b	4.58b	4.98c	1.56c	3.38c
	14	3.18a	2.20b	4.64b	4.92c	1.52c	3.96c
MAP	0	2.76a	4.98a	2.03a	2.33a	5.41a	.78a
	4	3.84b	3.73b	3.77b	3.70b	2.46b	2.14b
	7	3.66b	3.58b	4.04b	4.12b	1.94c	2.39b
	11	3.75b	2.74c	4.66c	4.27b	1.32d	4.75c
	14	4.12b	3.20bc	5.00c	4.35c	1.14d	4.20c
Cling	0	2.19a	5.03a	1.74a	2.33a	5.95a	.80a
	4	4.33b	3.05b	3.80b	3.85b	1.81b	3.58b
	7	4.48b	2.96b	4.42b	4.54c	1.76b	4.50b

Pack	Age (in days)	Bland odour	Juiciness of flesh	Chewing	First bite	Fried chicken flavour	Rancid flavour	Bland flavour
Vacuum	0	1.01a	5.93a	1.91a	1.23a	5.93a	.57a	.96a
	4	4.20b	2.42b	3.83b	3.68b	1.90b	1.65b	4.28b
	7	3.92b	1.68c	4.95c	4.82c	1.60bc	1.57b	4.18b
	11	3.79b	1.48c	5.29c	5.26c	1.12c	2.78c	4.31b
	14	3.71b	1.92bc	5.01c	4.85c	1.10c	3.34c	4.30b
MAP	0	1.56a	5.73a	2.01a	1.82a	5.49a	.90a	1.49a
	4	3.34b	3.67b	3.18b	2.91b	1.79b	2.47b	3.84b
	7	3.38b	2.76c	4.38c	4.27c	1.81b	2.24b	4.51c
	11	3.12b	2.28c	4.48c	4.29c	1.20c	4.42c	3.46b
	14	3.64b	2.23c	4.78c	4.33c	1.18c	3.67d	3.84b
Cling	0	.80a	6.01a	2.28a	1.77a	5.86a	.55a	.92a
	4	2.89b	2.40b	4.45b	4.31b	1.74b	2.94b	3.18b
	7	2.68b	2.03b	4.86b	4.71b	1.23b	4.27c	3.18b

Means in same column within packaging type bearing unlike superscripts differ significantly ($P < 0.05$).

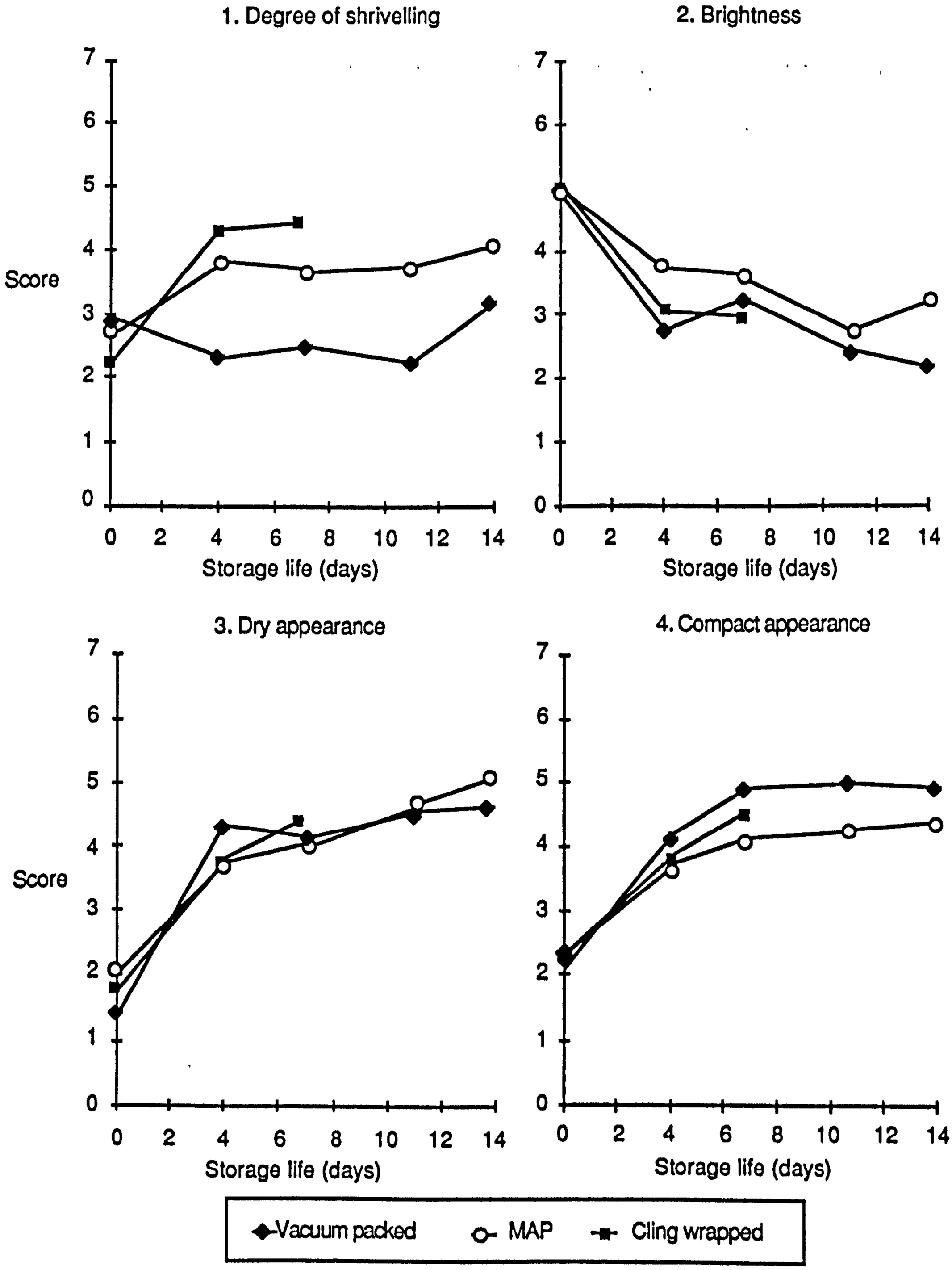
7.2.1. Appearance

The sensory attributes describing the appearance of the chicken drumsticks were shrivelling of skin, surface brightness, the compact appearance of the meat fibres and their dry appearance.

Shrivelling of the chicken skin was most pronounced in the cling wrapped samples and least apparent in the vacuum packed samples (Figure 7.1.1) where the drumsticks stored for 4, 7 and 14 days were not significantly different from the fresh sample (Table 7.2). Interaction between storage life and packaging was significant for shrivelling (Table 7.1), which indicates that the effect of storage life was dependent on the packaging which is clearly true (Figure 7.1.1). The significance of the effect of storage life was therefore recalculated by combining the interaction sum of squares with the error term b sum of squares, which reduced the level of significance for the storage life F value to below 0.025 in the first ANOVA model (Table 7.1).

Storage for seven days produced an average significant decrease ($P<0.05$) in the shrivelling score of 2.29 ± 0.74 for cling wrapped samples, compared with 0.9 ± 0.74 for MAP products and an increase of 0.44 ± 0.74 for vacuum packed samples. The increased permeability of the cling film would allow greater surface evaporation, possibly resulting in the skin contracting and producing a more shrivelled appearance.

Figure 7.1 Judges mean* scores for the appearance attributes of chicken drumsticks *mean of 8 judges and 5 replications of study



The surface brightness was also influenced by packaging type, but not significantly so (Figure 7.1.2). The loss of brightness was reduced during storage in the MAP samples, as compared with the vacuum and cling wrapped samples. The brightness of the vacuum packed drumsticks did not significantly change between 4 and 14 days of storage, whereas a progressive loss of brightness occurred during storage of the MAP samples (Figure 7.1a). This pattern was also true of the dry appearance of meat fibres (Figure 7.1.3.), which contrasts with the results of Mcdaniel et al., (1984) who found that vacuum packed beef roasts retained the "healthy bloom appearance" that they had acquired immediately after cooking, whereas those packed under CO_2 or a mixture of gases lost this bloom by 7 or 14 days.

The dry appearance of the meat fibres was significantly ($P<0.05$) greater in the cling wrapped drumsticks than in the MAP samples. For all packaging types the meat fibres became more compact with increased storage life (Figure 7.1.4).

7.2.2. Odour

Sensory attributes selected by the panel to describe the odour of the chicken drumsticks included fried chicken odour, rancid odour and bland odour. The term rancid was felt by the judges to express the strong chicken smell that developed with storage, that was not associated with the fresh roast or fried flavour apparent immediately after cooking. During discussion periods rancid was described frequently as stale and even as cardboardy, soapy and oily. Rancid odours and flavours are attributable to lipid oxidation. Several investigators have reported high correlations between increases in lipid oxidation and flavour changes in meats during refrigerated storage (Jacobson and Koehler, 1970; Harris and Lindsay, 1972; Arafa and Chen, 1976; Dawson and Gartner, 1983). The thiobarbituric acid (TBA) test is one of the most common methods of measuring degree of lipid oxidation, this and other methods are reviewed by Gray

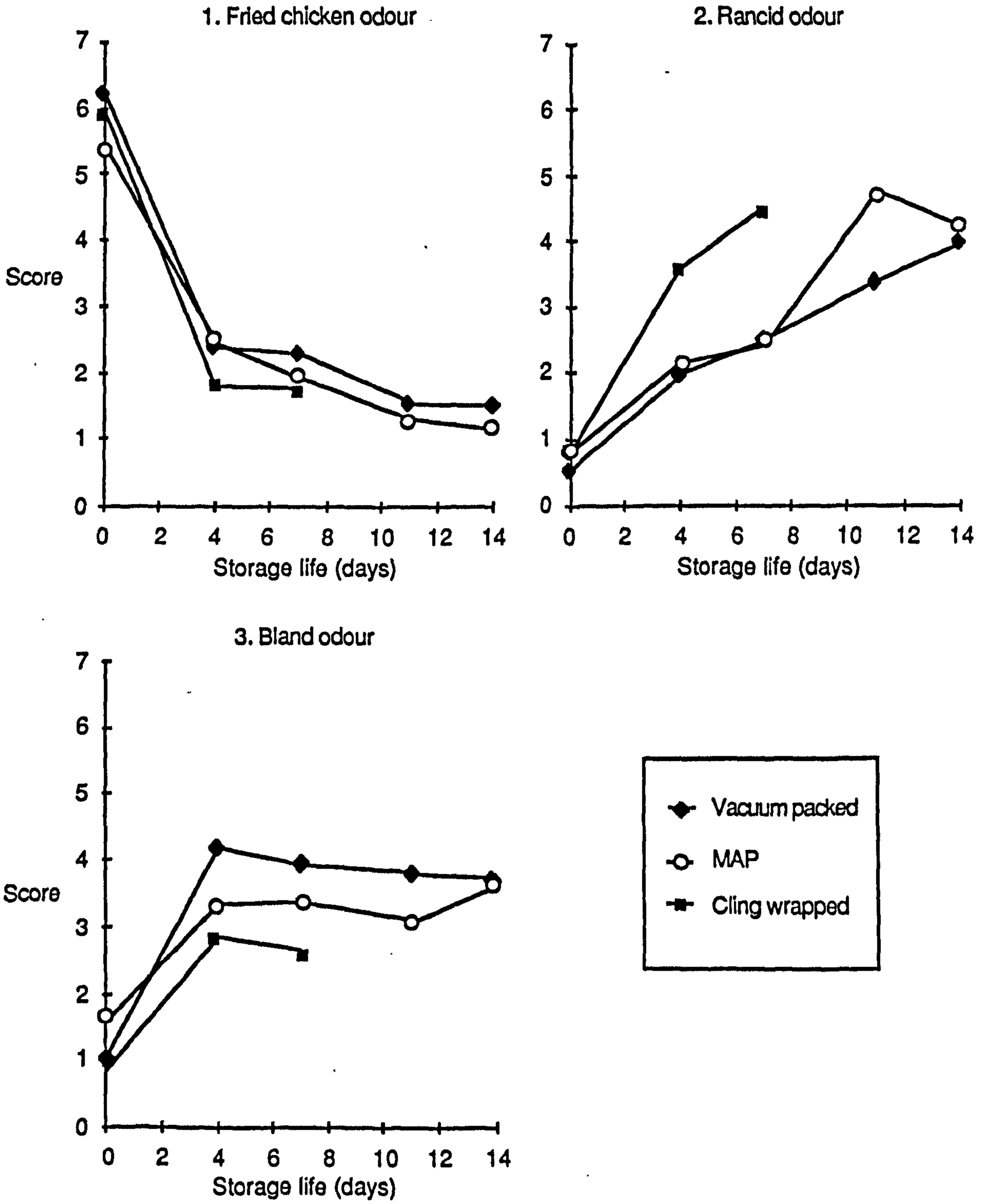
(1978). According to Pokorny et al., (1982) aldehydes produced by the decomposition of hydroperoxides are precursors of rancid flavours, while their interaction products with proteins, peptides and amino acids are the carriers of other off flavours.

In cooked meats rancid flavours are frequently described as "warmed over flavour" (WOF) and according to Enser (1985) are organoleptically different from rancidity in uncooked meats, probably because of the differences in the side reactions after hydroperoxide decomposition. The chemistry of the development of WOF in meats has been reviewed by Sato and Herring (1973). Denaturation of haem proteins with the release of iron and the disruption of the membrane structure which increases the accessibility of phospholipid polyunsaturated fatty acids are believed to be the cause (Enser, 1985).

Uebersax et al., (1978) and Jantawat and Dawson (1980) reported that vacuum and N_2 packed chicken and turkey meats showed similar TBA values and less lipid oxidation than did the meats packaged with CO_2 and air. Simard et al., (1983a) found no significant difference between the TBA values of vacuum or N_2 packed frankfurters stored for 49 days.

Glew et al., (1979) reported that TBA values of vacuum and N_2 packed cooked chicken and pork stored for 16 days rose only slightly compared with samples stored in air. For both meats the most rapid increase in TBA values occurred between 0 and 4 days which agrees with the current study, where the greatest increase in rancid odour and flavour for all packaging types occurred between 0 and 4 days (Figure 7.2.2 and 7.4.2). Harris and Lindsay (1972) also found that very little time was required for the initiation of off flavour development in precooked poultry stored at $6^{o}C$ for up to 5 days.

Figure 7.2 Judges mean scores* for the odour attributes of chicken drumsticks. *mean of 6 judges and 5 replications of study



Where all 3 packaging types were included in the ANOVA model (Table 7.1, model 1) the effect of packaging on rancid odour was significant, but not where only MAP and vacuum packed samples were being analyzed (model 2). The rancid odour score of the cling wrapped drumsticks significantly increased on average by 3.7 ± 0.99 after 7 days storage, compared with 1.94 ± 0.99 for vacuum samples and 1.61 ± 0.99 for MAP samples. Probably because of the differing effect of packaging on rancid odour, interaction between storage life and pack was significant ($P<0.001$) and so was included in the error term with which the F value for storage life was calculated, which resulted in reducing the significance level to $P<0.01$ (Table 7.1).

Fried chicken odour did not differ significantly between packaging types, but significantly ($P<0.001$) decreased with storage life, with the greatest loss occurring between 0 and 4 days for all packaging types (Figure 7.2.1).

The terms bland odour and also bland flavour were included on the score sheet during one of the last training sessions, when the judges felt it would be helpful to be able to score the absence of the fried chicken or rancid odour or rather score the presence of a mellow underlying chicken odour not characterized by the other attributes. Bland odour was significantly ($P<0.01$) affected by packaging type where all 3 packaging types were compared (Figure 7.2.3), but was not significant where only MAP and vacuum drumsticks were compared (Table 7.1, model 2). The vacuum and MAP samples tended to be more bland in odour than the cling samples. After storage for 4 days the bland odour score significantly increased ($P<0.05$) on average by 3.19 ± 0.75in vacuum samples, 1.78 ±0.75 in MAP drumsticks and 2.09 ± 0.75 in cling wrapped drumsticks, after which time the score did not significantly alter in the MAP and vacuum packed samples (Table 7.2).

7.2.3. Texture

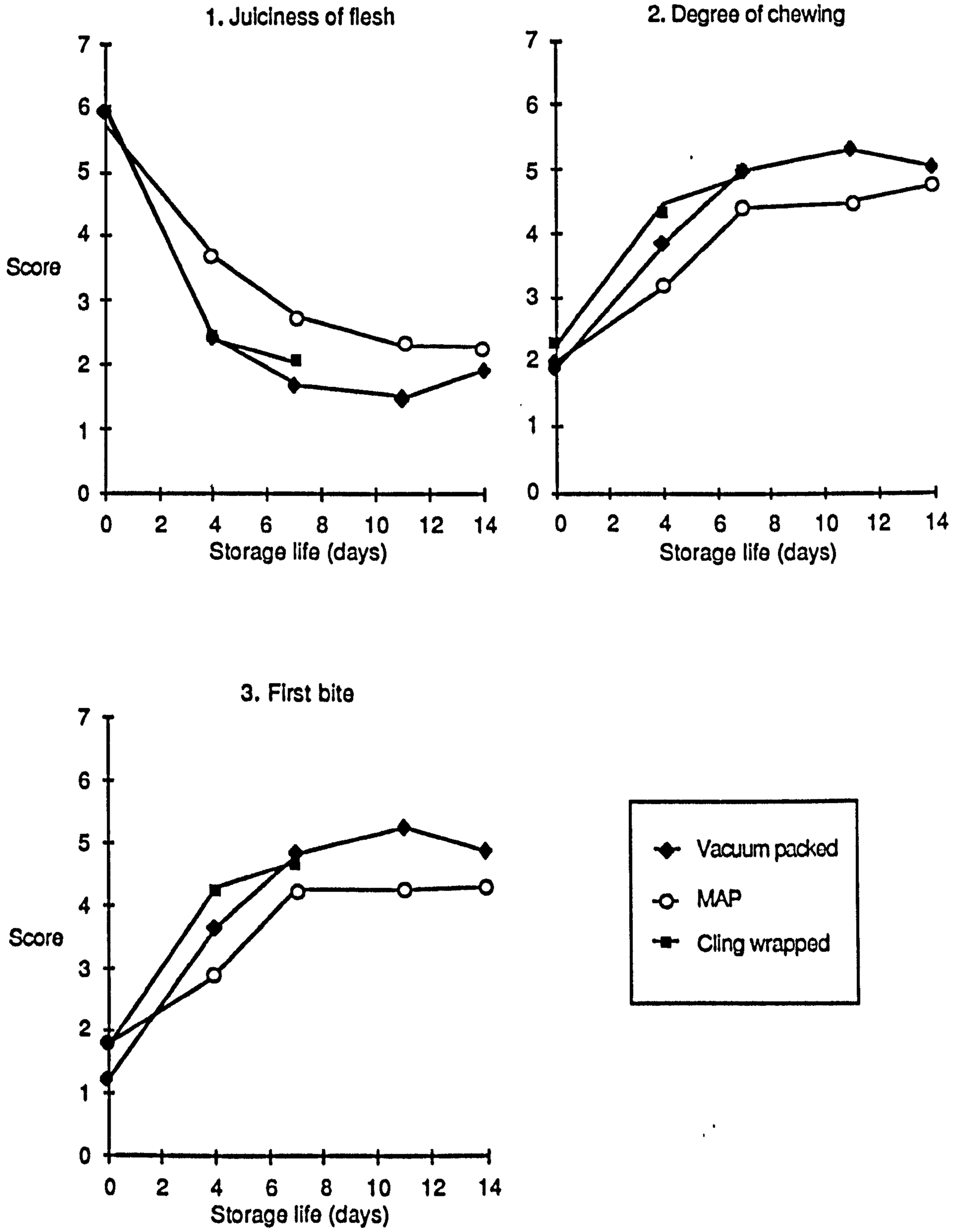
The textural attributes deemed to be important by the judges included first bite, juiciness of flesh and degree of chewing.

The degree of chewing required to reduce the samples to a form that was easily swallowed increased with storage time and was greatest in the vacuum packed samples, whose score significantly increased on average by 3.04 ± 0.67 after 7 days as compared to 2.37 ± 0.67 for MAP drumsticks and 2.58 ± 0.67 for cling wrapped drumsticks (Figure 7.3.2).

First bite refers to the degree of resistance presented by the meat fibres during the first molar incision. The scoring of first bite and juiciness of flesh between replications was significantly different ($P<0.01$) in model 1 and so the replications sum of squares was included in calculating error term (a) (Table 6.2). The new mean square error term (a) rendered the effect of packaging on first bite insignificant. However, the mean score for first bite of vacuum packed samples was consistently higher than the MAP or cling wrapped drumsticks and the mean score for juiciness was consistently lower in the vacuum packed samples (Figure 7.3.1. and 7.3.3). The vacuum packed drumsticks therefore appeared to be more resistant on first bite, required more chewing and were less juicy than the MAP or cling samples. Mcdaniel et al., (1984) found that vacuum packed pre-cooked beef roasts were less juicy ($P<0.05$) than MAP samples after 7 days storage, but after 21 days storage they were significantly ($P<0.05$) more juicy, at which time the vacuum samples were also lower ($P<0.05$) in moisture loss.

The first bite of samples became more resistant and drumsticks became less juicy with increased storage life, with the greatest effect occurring between 0 and 4 days and levelling off after 7 days (Figure 7.3).

Figure 7.3. Judges mean scores* for the texture attributes of chicken drumsticks. *mean of 8 judges and 5 replications of study



7.2.4. Flavour

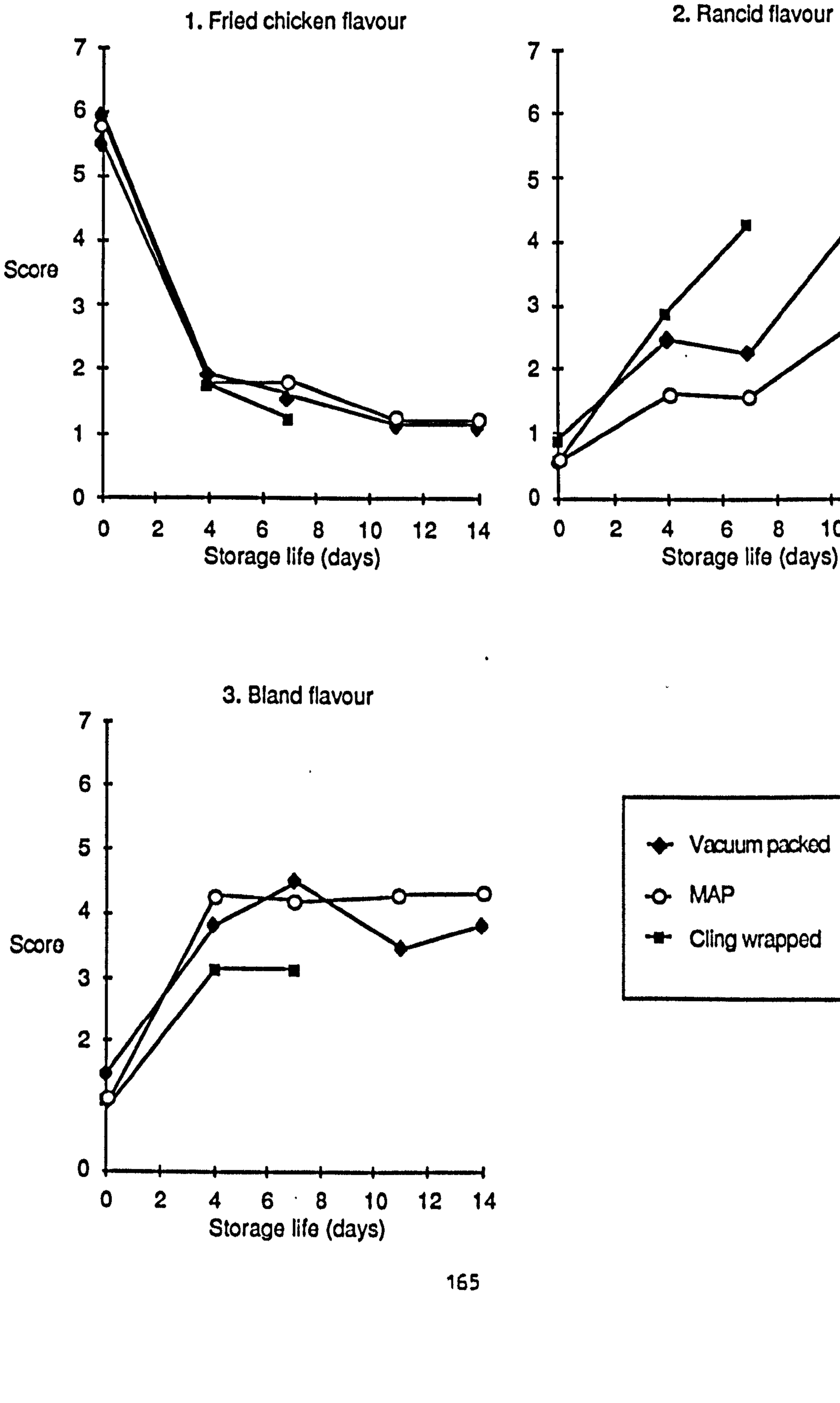
The flavours described by the judges corresponded to their perceptions of odour; fried chicken flavour, rancid flavour and bland flavour.

Fried chicken flavour was not affected by type of packaging, but was more affected by storage life than any other attribute studied, as it had the largest F value for storage life (Table 7.1), given the inclusion of appropriate significant effects in the error term. Pokorny et al., (1982) found that changes in odour and flavour in fried chicken and duck stored at 4°C were more pronounced than changes of other organoleptic properties. They showed that during storage the following flavours increased in intensity; gluey, fishy, rancid, stale and old. Fresh flavours other than 'meaty' were not mentioned.

The greatest mean decrease in fried chicken flavour occurred between 0 and 4 days; 4.0 ± 0.62 for vacuum packed samples 3.7 ± 0.62 for MAP samples and 4.12 ± 0.62 for cling wrapped samples (Figure 7.4.1). As the fried chicken flavour became weaker the rancid flavour became stronger; increasing on average by 1.8 ± 0.71 in the vacuum samples, 1.57 ± 0.71 in MAP drumsticks and 2.39 ± 0.71 in cling wrapped drumsticks after 4 days storage. (Figure 7.4.1). Rancid flavour like rancid odour developed during storage to a significantly ($P<0.05$) greater extent in cling wrapped drumsticks than in MAP or vacuum packed drumsticks (Table 7.1).

Unlike cling wrapped drumsticks where the largest increase in rancid flavour was between 0 and 4 days, the largest increase in rancid flavour in the MAP and vacuum drumsticks occurred between 7 and 11 days (Figure 7.4.2), thus demonstrating an inhibitory effect of MAP and vacuum packing on lipid oxidation.

Figure 7.4 Judges mean scores* for the flavour attributes of chicken drumsticks. *mean of 8 judges and 5 replications of study



Bland flavour of chicken drumsticks was significantly less in the cling wrapped samples (Table 7.1, model 1). This was attributed to the strong masking effect of rancid flavour over bland flavour. In MAP and vacuum packed drumsticks the greatest increase in bland flavour occurred after 4 days storage, after which time it levelled off (Table 7.2 and figure 7.4.3.).

7.3. Univariate analysis of chicken a la king

The experimental design employed in the analysis of chicken a la king was the same as that used in the sensory analysis of chicken drumsticks (see chapter 6, section 6.5) with the exception of fewer judges (6 instead of 8). Six judges took part in the experiment, but one judge was absent for 3 of the 19 sessions and so their scores for these samples were treated as missing data in the ANOVA. The experimental design is shown in Table 6.1. and breakdown of degrees of freedom in Table 6.2. The descriptive terms describing the sensory attributes are given in Table 6.5.

The chicken a la king was clearly a more complex product than the chicken drumsticks, consisting of a number of component parts (meat, sauce and vegetables), which were studied in both the cold and reheated state. It was felt necessary to evaluate the appearance of the cold product as it would be this form that the consumer would consider prior to purchase from a vending machine. The method of reheating by microwave mirrored methods used in the vending industry.

The complete three way ANOVA tables are given in Appendix 8 and a summary of the F values for each sensory attribute and model in Table 7.3. The mean scores for each sample and attribute are presented in Table 7.4.

In contrast with the chicken drumsticks not all the sensory attributes of chicken a la king selected by the

judges were affected by storage life. Most that were related to the appearance of the cold chicken a la king and in particular the appearance of the sauce. In the stored samples this became more granular, more gelatinous, less able to coat the vegetables and had a reduced depth of colour. Also its mouthfeel was less smooth and the odour and flavour of the sauce became increasingly stale upon storage.

Where the effect of packaging on the sensory quality of the chicken a la king was significant ($P<0.05$) the results were not always clear, because the scoring of the standards which were included with each group of samples varied, which suggests that the period of time elapsing between judgements of the different sample groups may have caused a drift in scoring scales, resulting in apparent differences between samples.

Table 7.3 F values for three way ANOVA of chicken a la king

Model 1; 3 levels of packaging, 3 levels of storage life (0,4 and 7 days), 6 judgments and 5 replications of study.

	Granular	Gelat -inous	Depth of colour	Sauce coating	Meat appear -ance	Pea colour
Whole plots						
R	7.38b	1.33	6.36c	2.19	28.44a	2.04
P	0.45	1.11	13.53b(1)	0.51	14.29b(2)	2.75
Split plot						
A	9.72b	6.75b	36.51a	32.54a	5.33c	35.98a
RA	0.80	0.70	0.37	0.75	0.35	0.89
PS	0.40	0.23	0.32	0.11	0.16	2.05
Split split plots						
T	1.18	1.41	1.68	0.87	0.50	0.38
RT	0.20	.04	0.16	0.14	0.14	0.17
PT	0.98	.12	0.12	0.02	0.18	0.08
AT	0.99	.92	1.08	0.55	0.35	0.37

	Range of pea colour	Surface oil	Sauce odour	Chicken odour	Sauce texture	Meat texture
Whole plots						
R	0.27	5.06c	2.01	0.70	1.78	3.83
P	1.35	3.51	0.67	1.26	1.42	0.69
Split plot						
A	7.61b	3.66d	7.89b	1.80	7.95b	0.55
RA	0.40	0.81	0.52	0.40	0.43	1.04
PS	0.10	1.99	0.27	0.43	0.72	0.50
Split split plots						
T	1.28	0.11	0.73	0.86	1.24	0.37
RT	0.20	0.18	0.10	0.18	0.04	0.10
PT	0.13	0.13	0.05	0.10	0.08	0.14
AT	0.85	0.24	0.47	0.62	0.68	0.29

	Pea texture	Stale flavour	Acidic flavour	Sweetness	Saltiness	Chicken flavour
Whole plots						
R	2.93	2.86	2.82	3.03	0.75	1.18
P	0.77	2.38	0.77	0.95	0.96	1.06
Split plot						
A	0.44	6.04c	0.05	1.02	1.68	2.29
RA	0.53	0.65	1.34	0.55	0.65	0.42
PS	0.78	0.86	0.22	0.40	0.03	0.22
Split split plots						
T	0.24	2.46d	2.48d	2.26d	1.86	1.75
RT	0.17	0.12	0.35	0.27	0.30	0.45
PT	0.19	0.12	0.46	0.33	0.23	0.20
AT	0.39	1.51	1.52	1.50	1.15	0.97

Model 2; 2 levels of packaging (MAP and vacuum packaging), 5 levels ofstorage life (0,4, 7, 11 and 14 days), 6 judgments and 5 replications of study.

	Granular	Gelat -inous	Depth of colour	Sauce coating	Meat appear -ance	Pea colour
Whole plots						
R	1.05	2.22	6.33	0.82	9.22d	4.56
P	0.18	0.23	5.73	1.71	24.65b(3)	40.76b
Split plot						
A	7.28b	10.52a	24.47a	24.81a	16.59a	24.46a
RA	0.99	1.79	0.51	1.45	1.77	1.19
PS	1.18	0.55	1.65	1.70	2.74	5.8
Split split plots						
T	1.49	1.51	1.18	0.93	0.61	0.14
RT	0.72	.10	0.24	0.15	0.18	0.14
PT	0.26	.13	0.11	0.14	0.05	0.22
AT	0.78	.52	1.51	0.37	0.32	0.22

	Range of pea colour	Surface oil	Sauce odour	Chicken odour	Sauce texture	Meat texture
Whole plots						
R	1.36	0.86	0.07	3.64	3.05	1.95
P	0.02	6.90	0.98	10.72d	0.48	0.06
Split plot						
A	5.62b	1.72	3.97d	0.19	8.59a	0.26
RA	0.90	1.52	0.43	0.81	0.62	1.21
PS	0.42	4.35d	0.74	1.21	1.33	0.74
Split split plots						
T	2.31	0.14	0.32	1.07	1.57	0.37
RT	0.36	0.08	0.08	0.20	0.06	0.04
PT	0.26	0.16	0.04	0.08	0.07	0.17
AT	0.33	0.13	0.19	0.49	0.45	0.21

	Pea texture	Stale flavour	Acidic flavour	Sweetness	Saltiness	Chicken flavour
Whole plots						
R	2.46	3.20	1.53	4.64	0.77	2.05
P	3.37	2.69	0.26	0.70	0.12	0.24
Split plot						
A	1.37	6.21b	0.98	1.74	0.55	0.53
RA	0.36	1.13	0.91	1.11	0.58	0.80
PS	1.13	4.95	0.40	0.91	0.07	1.24
Split split plots						
T	0.23	1.86	1.38	2.12	1.38	0.53
RT	0.28	0.15	0.30	0.14	0.31	1.04
PT	0.25	0.06	0.05	0.08	0.18	0.03
AT	0.24	0.68	0.48	0.76	0.64	0.92

R: replication
T: judge
A: storage life
P: packaging

a: P<0.001
b: P<0.01
c: P<0.025
d: P<0.05

Recalculated F values for packaging when significant replication effects are combined in the error term.
(1) F value for packaging=4.85 P<0.05
(2) F value for packaging=1.41 P>0.05
(3) F value for packaging=4.97 P>0.05

Table 7.4 Mean scores* for sensory evaluation of chicken a la king given as different packaging treatments presented as days within packaging type.

* 6 judgements, 5 replications of study and scale of 0 to 15.

Pack	Age	Granular	Gelat-inous	Depth of colour	Sauce coating	Meat appearance	Pea colour
Vacuum	0	3.40a	4.13a	7.99a	7.10a	7.49a	2.06a
	4	5.69b	5.47b	5.16b	4.42b	5.68b	3.61a
	7	5.39b	5.28b	4.60bd	4.45b	5.13bc	4.61b
	11	6.60c	6.55c	3.32 c	3.92b	5.25bc	4.68b
	14	5.46b	6.79c	4.00 d	3.84b	4.55c	4.08b
MAP	0	4.06a	4.19a	7.01a	7.36a	6.77a	1.74a
	4	5.18b	6.01b	4.34b	4.65b	4.71b	4.52b
	7	5.20b	5.62b	3.86bc	4.90b	4.89b	5.52cd
	11	5.78b	5.92b	3.49c	5.09b	4.16b	6.07d
	14	4.86b	7.02c	3.68bc	3.62c	4.14b	6.39d
Cling	0	3.94a	4.69a	6.41a	6.91a	6.94a	2.82a
	4	6.15b	5.92b	3.99b	4.51b	4.99b	4.75b
	7	5.41b	6.48b	4.04b	4.85b	5.64b	4.51b

Pack	Age (in days)	Range of pea colour	Surface oil	Sauce odour	Chicken odour	Sauce texture	Meat texture
Vacuum	0	2.98a	6.40a	4.21a	3.97	7.95a	5.09
	4	5.10b	4.68b	5.93b	3.60	6.40bc	5.28
	7	4.86bc	4.12b	5.37b	3.63	6.89b	5.49
	11	5.13 b	5.42b	5.59b	3.23	5.87c	5.02
	14	3.93 c	4.09c	6.16b	3.69	6.18bc	4.89
MAP	0	2.49a	5.08a	3.64a	4.64	7.32a	4.64
	4	5.19b	6.16b	4.93b	4.06	6.23b	5.50
	7	4.61b	5.37ab	5.39b	4.14	6.36b	4.77
	11	5.00b	5.80ab	5.44b	4.10	6.14b	5.36
	14	4.86b	5.76ab	5.49b	3.62	6.54b	5.50
Cling	0	3.75a	5.33a	4.24a	4.78	7.46a	5.17
	4	5.65b	4.57ab	5.79b	3.41	6.94b	5.19
	7	5.20b	3.58b	5.43b	3.00	6.29b	6.10

Means in same column within packaging type bearing unlike superscripts differ significantly ($p<0.05$)

Table 7. (continued)

	Age (in days)	Pea texture	Stale flavour	Acidic flavour	Sweetness	Saltiness	Chicken flavour
Vacuum	0	4.77	4.31a	4.30	3.83	4.70	4.79
	4	4.92	5.83b	3.93	4.55	4.00	4.22
	7	5.34	5.37b	3.90	4.63	4.38	4.17
	11	5.15	5.94b	4.02	4.32	4.29	7.77
	14	5.79	5.54b	5.27	4.61	4.32	4.15
MAP	0	5.15	4.22a	4.24	4.21	4.90	5.60
	4	6.49	4.44a	4.56	4.73	4.25	4.64
	7	4.94	4.70a	4.44	4.02	4.54	4.97
	11	5.87	4.51a	4.33	4.41	4.25	3.81
	14	7.02	6.52b	4.85	5.42	4.33	4.19
Cling	0	5.20	3.95a	3.80	3.69	4.54	5.34
	4	5.16	5.49b	4.31	4.02	3.55	4.19
	7	5.31	5.36b	4.29	3.86	4.13	3.84

Means in same column within packaging type bearing unlike superscripts differ significantly ($p<0.05$)

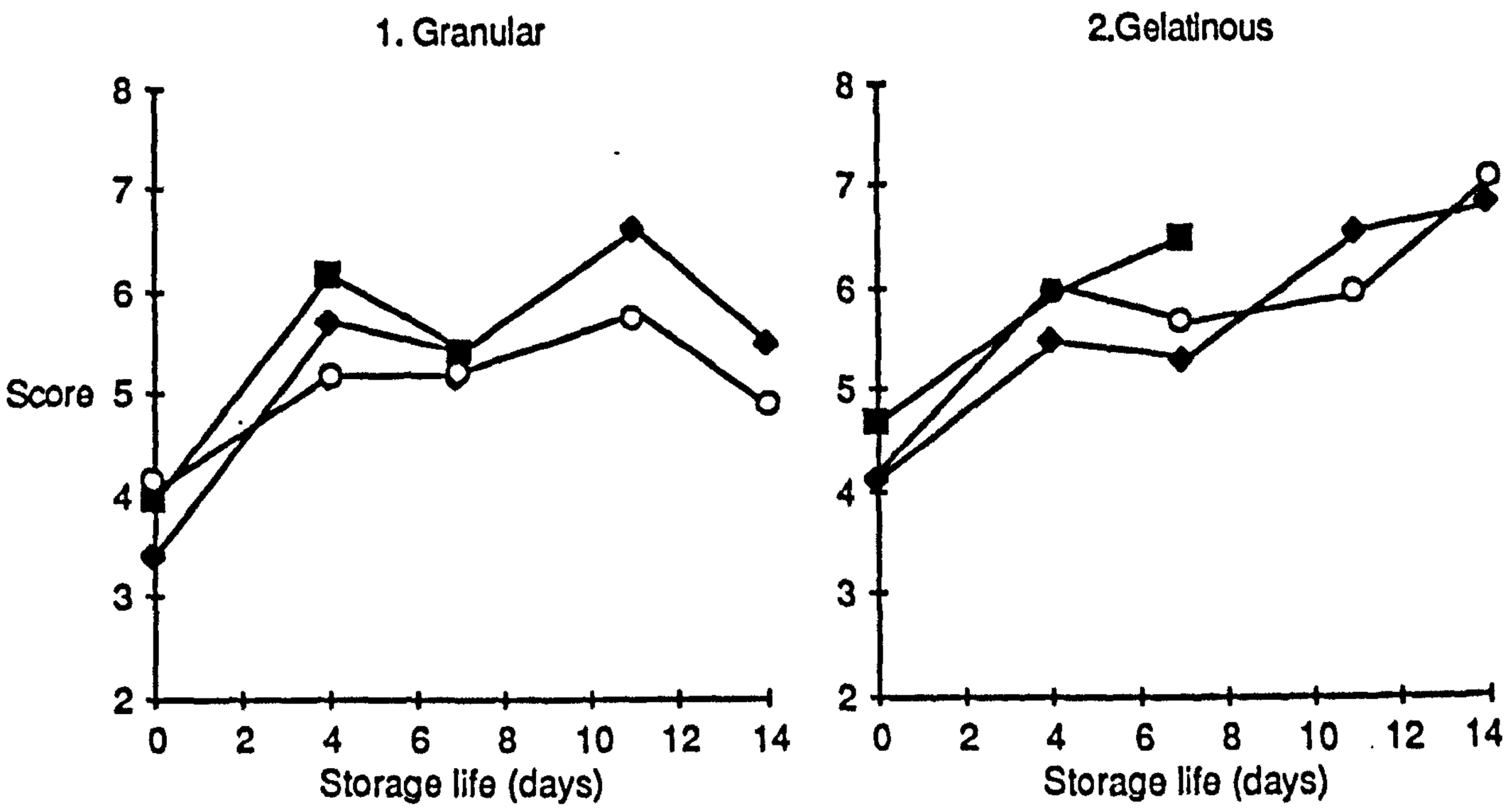
7.3.1. Appearance

Eight (44%) of the eighteen sensory attributes pertained to appearance; five referred to the the sauce, one to the meat and two to the peas. All the appearance characteristics were significantly ($P<0.05$) affected by storage life and the greatest changes occurred between 0 and 4 days, after which time results varied with different attributes.

The granular or pastey appearance of the sauce was characterized by the appearance of visible grains and was accompanied by liquid separating out from the sauce. This was attributed to retrogradation of starch, where the individual molecules were not sufficiently entangled to form a gel and so the growing micelles eventually caused precipitation and resulted in a curdled or granular appearance. After the initial significant increase in granular appearance, the scores levelled off and even decreased slightly after 14 days (Figure 7.5.1). MAP samples were less granular than cling or vacuum packed samples throughout storage but not significantly so.

The gelatinous appearance of the sauce referred to the transformation of the sauce from a sol into a gel due to the inter molecular bonding between starch molecules resulting in a 3 dimensional network entrapping substantial amounts of water. The sauce gel became significantly ($P<0.05$) firmer (more 'set') with increased storage (Figure 7.5.2.). Cremer et al., (1985) attributed clumping of cooked noodles after 2 weeks of refrigerated storage to gelatinization of starch.

Figure 7.5 Judges mean scores* for the appearance attributes of the chicken a la king sauce. *mean of 6 judges and 5 replications of study



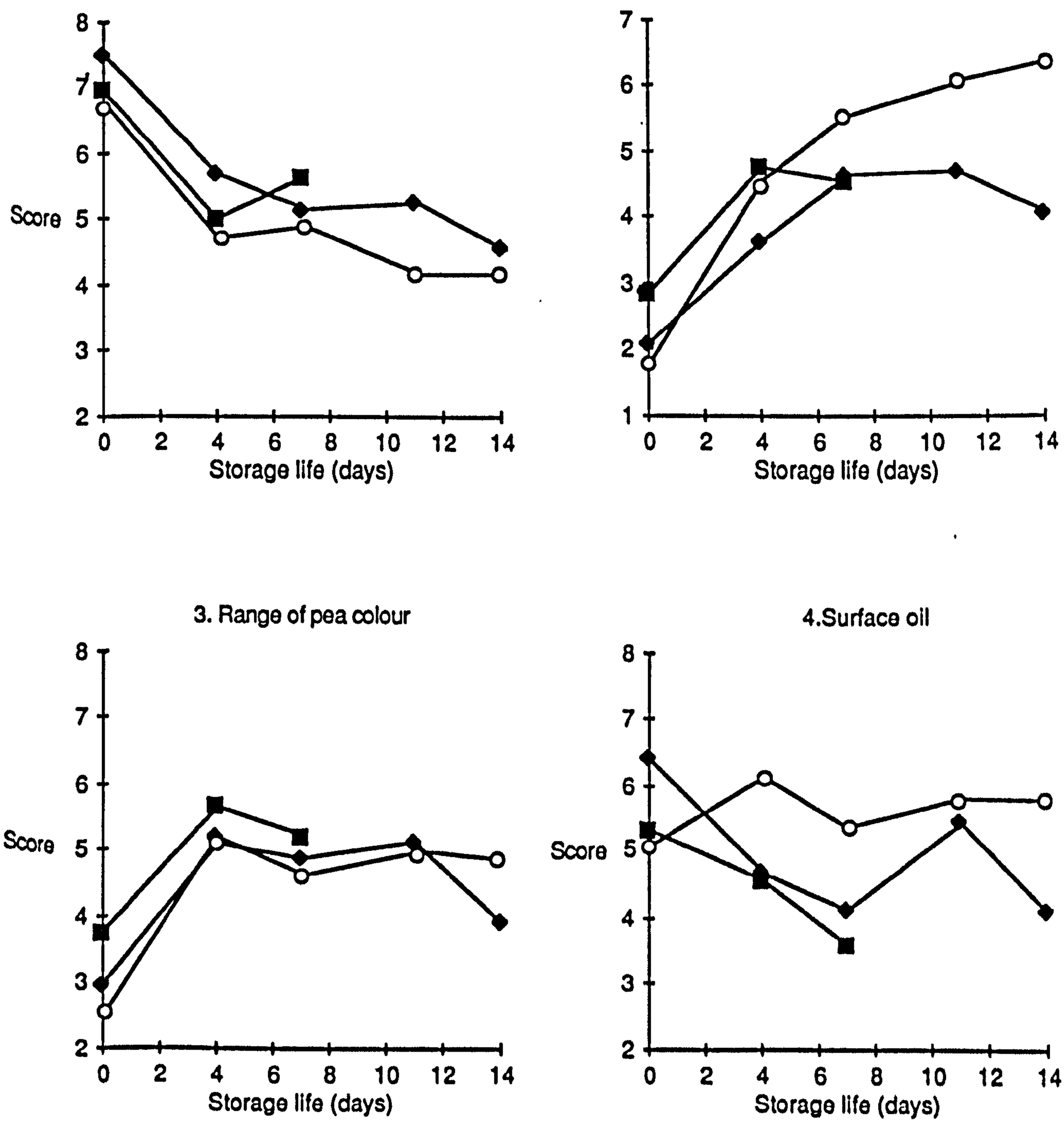
The depth of colour of the sauce reflected the hue; as the original colour of the sauce faded and lost its brightness, it was said to have lost its depth of colour. This attribute had the highest F value for storage life and continued to significantly decrease between 4 and 14 days of storage (Figure 7.5.3.). Cremer et al., (1985) found that the colour of freshly prepared sauce appeared close to white, but was significantly ($P<0.01$) more yellow after 2 and 4 weeks of refrigerated storage and heating.

The ability of the sauce to coat the peas and pimentos was reflected in the attribute sauce coating, which decreased significantly between 0 and 4 days, after which time it levelled off and was not significantly affected by packaging type.

In the first ANOVA model (Table 7.3) where all three packaging types were compared significant ($P<0.05$) differences in depth of colour were apparent between packaging types. However, even the day 0 samples which were included as standards with each group of packaged samples were scored differently (Figure 7.5.3), which suggests that differences due to packaging types were partly due to the periods of time elapsing between judges scoring of groups of samples, which may have caused a drift in the depth of colour scale and apparent differences between packaging. Also the replications were scored significantly different ($P<0.05$) and so were included in the calculation of the error term, which reduced the significance of the effect of packaging from 0.025 to 0.05.

Meat appearance referred to the stringy appearance of the chicken meat. This characteristic was significantly different between the packaged samples as calculated in both models (Table 7.3). The MAP chicken a la king appeared significantly more broken up than the vacuum packed or cling wrapped samples (Figure 7.6.1).

Figure 7.6 Judges mean scores* for the appearance attributes of the chicken a la king *mean of 6 judges and 5 replications of study



The pea colour varied from a fresh pea green to olive through to khaki and the colour of the peas was not uniform throughout the sample, hence the term, pea colour range. The colour degradation was attributed to the conversion of chlorophyll to pheophytin, due to the replacement of the central magnesium atom in the tetrapyrrole ring by hydrogen and the consequent formation of dull olive brown pheophytins. Other colour reactions may also have occurred but would have been limited compared with pheophytinization, for example the rupture of the tetrapyrrole ring to form colourless end products. Heat processing may inactivate deteriorative enzymes, but oxidative reactions causing chlorophyll losses are initiated. The pea colour changed significantly with storage life in all packaged samples, becoming less pea green and more olive with time. Pea colour was the sensory attribute most affected by type of packaging. The original pea green colour was lost at a significantly ($P<0.05$) faster rate in the MAP samples than in the vacuum packed samples (Figure 7.6.2). The extent of pheophytinization is dependent on the processing temperature, storage time, storage temperature and product pH (Fennema, 1976). The first three of these variables were standardized amongst samples but the pH of the surface of the MAP chicken a la king was lower (5.85 ± 0.1) than the vacuum packed chicken a la king (6.2 ± 0.1), probably due to the solubilization of CO_2 in the product surface (see chapter one, section). The pH difference may have accounted for the greater degree of pheophytinization in the MAP samples (Figure 7.6.2). The uniformity of pea colour also decreased with storage (Figure 7.6.3).

Once reheated in the microwave, judges evaluated the amount of oil on the surface of the chicken a la king samples. The effect of scoring between replications was greater ($P<0.025$) in model 1 than the effect of packaging ($P<0.05$). This inconsistency in the judges mean scores was also reflected in the different mean scores assigned to the standards (Figure 7.6.4). During reheating in the microwave

uneven patterns may have caused in part the variation between replications. However the effect of replications was insignificant when only MAP and vacuum products were compared. Mcdaniel et al (1984) also noted that the effects of storage and packaging on cooked beef roasts may have been concealed by the reheating of samples in a microwave oven as after heating samples appeared unevenly cooked.

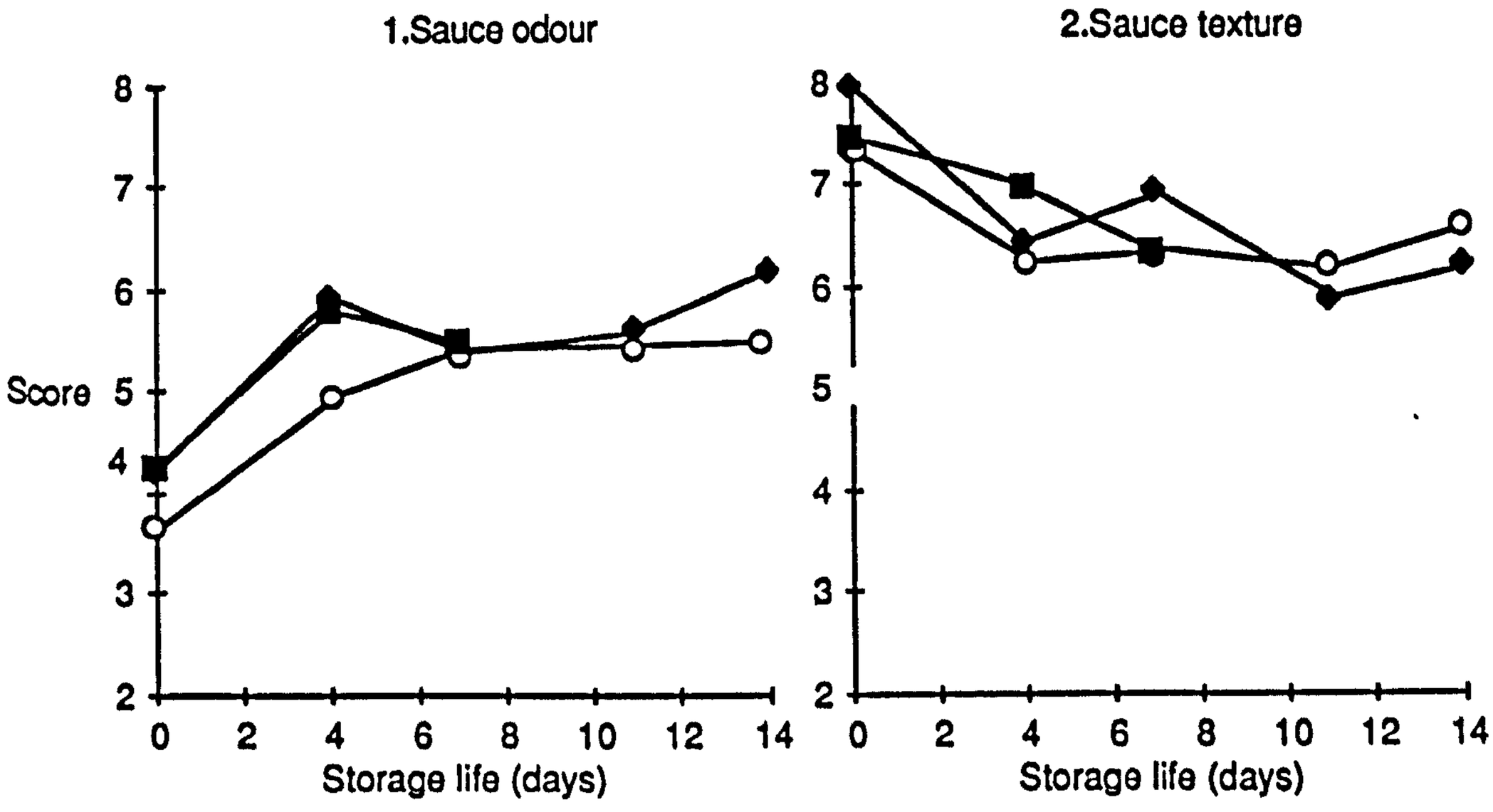
7.3.2. Odour

The strength of chicken odour and the freshness of the sauce odour were the odour attributes of chicken a la king selected by judges.

The chicken odour did not significantly vary over storage time or between packaging types in model 1 (Table 7.3) although the scores were lower for the stored cling wrapped chicken a la king (Figure 7.7.4). In ANOVA model two, however, there was a significant ($P<0.05$) difference between the chicken odour of MAP and vacuum samples. Overall the vacuum packed samples tended to have lower scores ie had less of a chicken smell. However, as found with depth of colour, the standards were scored differently and therefore any variations attributable to packaging may have been a result of different use of the scales during different scoring sessions. Between 0 and 14 days of storage the odour of the sauce in all packed samples became significantly ($P<0.05$) more stale (Figure 7.7.1). The increase in stale odour of the sauce continued after 4 days of storage and was significant ($P<0.05$) for the vacuum packed samples but not the MAP samples (Figure 7.7.1.).

Figure 7.7 Judges mean scores* for the sauce odour, sauce texture and sauce flavour of the chicken a la king.

*mean of 6 judges and 5 replications of study



7.3.3. Texture

The rate of breakdown of the meat on chewing and the pea texture were not significantly influenced by any of the effects examined in the study (storage life, packaging, replication or judge). The texture of the sauce however became significantly less smooth and coarser with storage time, with the largest effect occurring between 0 and 4 days (Figure 7.7.2.).

7.3.4. Flavour

Judges selected five attributes to describe the flavour of the chicken a la king; stale flavour, acidic flavour, sweetness, saltiness and chicken flavour. Only stale flavour was significantly affected by length of storage time (Figure 7.7.3). In vacuum and cling wrapped samples the stale flavour of the sauce became significantly stronger between 0 and 4 days whereas a significant increase in stale flavour did not occur in MAP samples until 14 days of storage (Table 7.4), although differences in stale flavour between packaging types were not significant (Table 7.3).

The other flavour attributes selected by judges are probably useful descriptive terms of chicken a la king, particularly if the raw materials or the recipe formulation are the variables under study. However, in this experiment where all the variables with the exception of storage time and packaging were standardized, no differences in these attributes were found between samples, with the exception of stale flavour. These results agree with Cremer et al., (1985) who found that no component of flavour in chicken in sauce and noodles prepared in a hospital foodservice system was affected by storage for up to four weeks at $0.2 \pm 0.6^{o}C$.

The absence of rancid or warmed over flavours (WOF) which were characteristic of the chicken drumsticks may have been due to the masking effect of the sauce and accompanying

vegetables. Enser (1985) pointed out that the development of WOF is inhibited in many cooked products by the addition of spices, herbs, vegetables or certain cereal extenders.

7.4. Multivariate statistical analyses

It can be seen from the results of the univariate analyses that the effect of packaging and storage life on chicken drumsticks is complex, influencing the 13 product attributes simultaneously. However, it is unlikely that each judge is able to assess each attribute independently, as they would be influenced by previous scores for that sample and in reality it is improbable that all 13 attributes were independent as they were all subject to the same influences, namely storage life and packaging. It would be extremely useful if the inter-relationships between attributes could be determined and the number of attributes reduced to a smaller number of variables independent of each other which described the main differences between samples. Several investigators have shown that many sensory attributes of a food may be reduced to a few without loss of information (Frijters, 1976; Horsfield and Taylor, 1976; Lyon, 1980), which suggests that the sensory profiles of many foods have a simpler perceptual structure than assumed by judges. Syarief et al (1985) applied principal component analysis to flavour profile data of beefsteaks, fish gels, frankfurters, peanuts, peanut butters and baked sweet potatoes. They found that the underlying dimensional structure had a number of dimensions equal to approximately one third of the descriptive terms, which explained 75% of the total variance. Data reduction and the identification of underlying relationships were the main aims of the following multivariate analyses.

7.4.1. Stepwise discriminant analysis (SDA) of chicken drumsticks.

Discriminant analysis is an exploratory technique that allows observed differences between samples to be

investigated when the causal relationships are not well understood. It may also be used to develop well defined rules that allow samples of unknown origin to be classified.

SDA was particularly appropriate in this study because it allowed groups of samples to be defined, which in this case were related to the packaging type and storage life of samples (13 groups). The characteristics of these groups were measured by a collection of discriminating variables; in this study the 13 sensory attributes. The analysis formed one or more linear combinations of the variables (sensory attributes), known as discriminant functions. Thus each discriminant function is made up of a combination of the original sensory attributes. Each attribute is strongly related to one of the discriminant functions, the strength of the relationship is indicated by the absolute value of its weighting coefficient (otherwise known as standardized discriminant function coefficients). The weighting coefficients of each sensory attribute facilitate interpretation of the discriminant functions. The number of functions formed equalled the number of groups specified by the researcher, but not all the discriminant functions may be required for discrimination. In this study the number of discriminant functions retained was dependent on the significance on the chi-squared value associated with Wilks Lambda, which is indicative of the amount of discriminating power left in the remaining discriminant functions (Nie et al., 1975).

The stepwise procedure first selects the single best discriminating variable, followed by the second best and so on. At each step variables already selected may be removed if they are found to reduce discrimination when combined with more recently selected variables. Eventually either all the variables will have been selected or the remaining variables no longer contribute to further discrimination. The criterion for selection of variables in this study was based on the overall multivariate F ratio for the test of differences among mean discriminant scores (centroids). It therefore

takes into consideration differences between centroids and the cohesion (homogeneity) within groups (Nie et al , 1975).

In order to increase the percentage variance contained in the first few discriminant functions the numbers of groups specified in the analyses were varied. Initially all 13 sample groups were specified, which meant that there were 3 groups of fresh drumsticks (unpackaged and not stored). In later anlayses these 3 groups were combined into 1 group, which reduced the number of sample groups to 11.

Table 7.5 gives the eigenvalues and variance explained for the discriminant functions retained in each of the analysis. The SDA summary tables for each analyses produced by SPSS are shown in Appendix 9. Eigenvalues and associated cannonical correlation coefficients denote the relative ability of each function to separate the groups.

Table 7.5 The eigenvalues and percentage variance of the retained discriminant functions.

Discriminant function number	The group composition of the SDA A	B	C	D
Eigenvalues				
1.	2.02	1.99	2.11	2.08
2.	0.33	0.33	0.37	0.36
3.	0.11	0.11	0.13	0.13
Variance				
1.	77.34a	77.95a	77.16a	77.8
2.	12.81a	12.85a	13.53a	13.55a
3.	4.33b	4.25b	4.86a	4.76a
% Cumulative Variance	94.48	95.04	95.56	96.19

Significance of chi-squared: a; P<0.001, b; P<0.025
A: All 13 groups.
B: 11 groups (3 groups of fresh samples combined into 1 group)
C: 11 groups (samples stored for 14 days not included)
D: 9 groups (fresh samples combined into 1 group and samples stored of 14 days not included).

When all 13 groups were included in the analyses 94.48% of the original variance was included in the first 3 discriminant functions. Degree of chewing was not included in

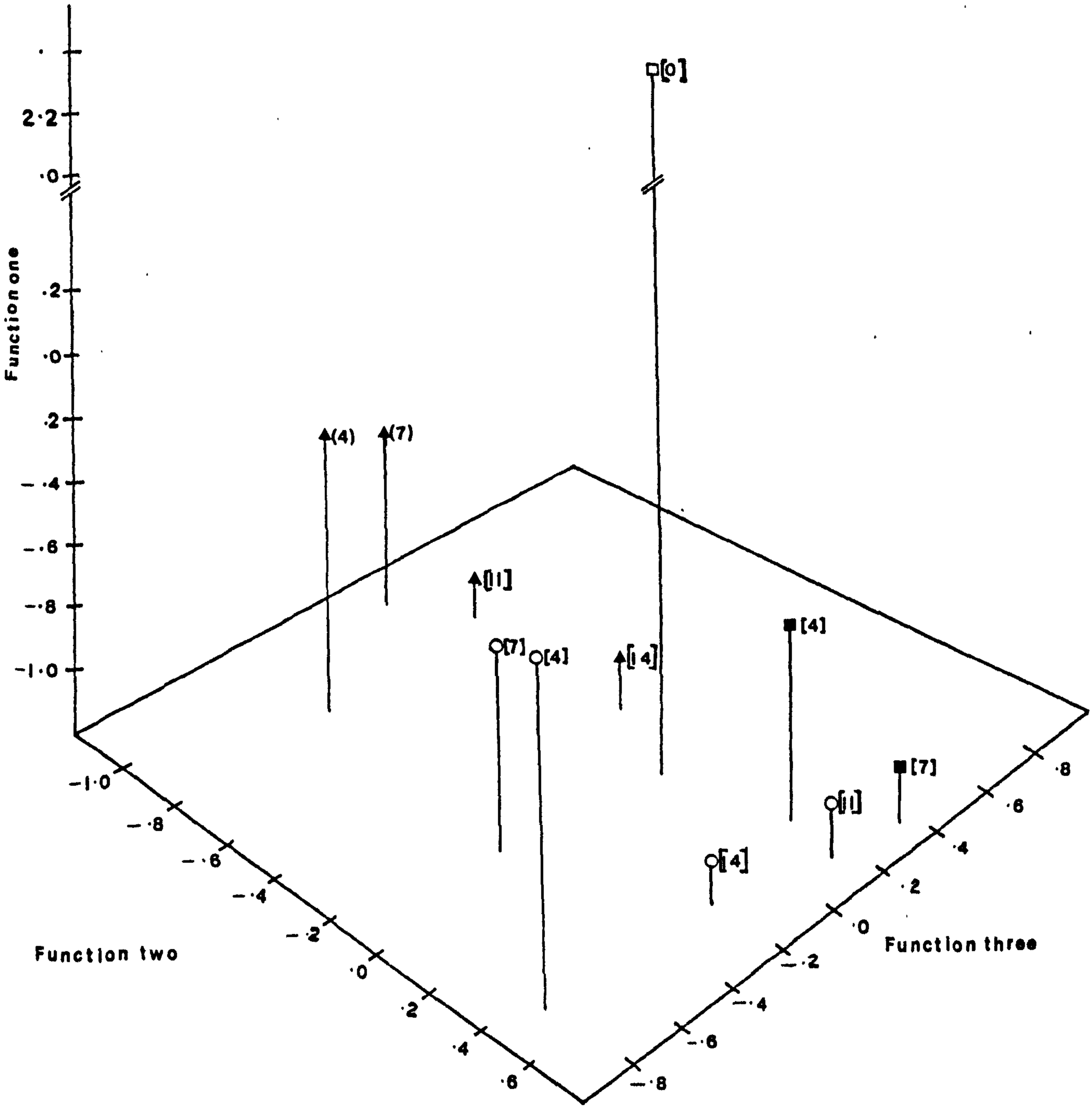
the analyses as its associated F value was insignificant. Cumulative variance was increased to 95.04% when the fresh samples were included in a single group. Each step in the analyses and the corresponding values for Wilks lambda were very similar to those calculated when the fresh samples were in 3 separate groups (summary tables are shown in Appendix 9).

Frijters (1976) found that a seven dimensional textural space of cooked chicken breast meat could be reduced to 3 dimensions by means of principal component analysis, with a loss of 14.7% of the original variance. The 3 factors corresponded to a 'mechanical' factor (hardness, cohesiveness, elasticity and chewiness), a 'fluidity' factor (dryness and roughness) and a 'fattiness' factor.

The selected discriminant functions may be regarded as the dimensions of space, in which the mean discriminant scores for each sample and the weighting coefficients of each sensory attribute may be plotted. Thus a 13 dimensional space which is impossible to visualize let alone interpret, may be reduced to a 2 or 3 dimensional space, in which the underlying relationships become apparent. A three dimensional plot of all 13 groups is shown in Figure 7.8.

Figure 7.8 Mean discriminant scores* of chicken drumsticks plotted on the first three discriminant functions.

* SDA of 11 samples, 0 days standards combined in one group.



■ Cling wrapped

○ MAP

▲ Vacuum packed

□ 0 day standard

Numbers in parentheses are storage life in days

The first discriminant function contained a large proportion (>77%) of the original variance (Table 7.5). It may be seen from Figure 7.8 that it corresponded to storage life; storage life increased as the discriminant score decreased. Attributes with large positive weighting coefficients on this function and therefore related to the fresh samples (which are situated on the right of discriminant function one) include fried chicken flavour, juiciness of flesh and fried chicken odour (Table 7.6). In contrast to this study, where the attributes contributing most to separation of samples was chicken flavour, Lyon (1980) found that texture, followed by juiciness, then flavour and then appearance made most contribution to differentiation between 6 canned boned chicken products. However, the sample treatments in the two studies were different and therefore not directly comparable.

Table 7.6 The discriminant function coefficients of each sensory attribute.

Attribute		Function 1	Function 2	Function 3
1.	Shrivelling	-0.07	0.68	-0.08
2.	Brightness	0.02	0.13	-0.30
3.	Dry appearance of flesh	-0.13	-0.03	-0.37
4.	Compact appearance of flesh	-0.09	-0.28	0.13
5.	Fried chicken odour	0.23	-0.22	0.29
6.	Rancid odour	-0.14	0.16	0.60
7.	Bland odour	-0.07	-0.23	-0.08
8.	Juiciness	0.31	0.26	-0.29
9.	First bite	-0.09	-0.39	0.47
10	Fried chicken flavour	0.47	-0.13	0.27
11.	Rancid flavour	-0.08	0.52	-0.11
12.	Bland flavour	-0.35	-0.80	-0.39

The second and third discriminant functions contained far less of the original variance and appeared to be related to the packaging types, in that they separated the 3 packaging groups. Function 2 separated the vacuum packed drumsticks from the MAP and cling drumsticks (Figure 7.8),

although the MAP drumsticks stored for 7 days had a similar score on discriminant function 2 as the vacuum packed samples stored for 14 days.

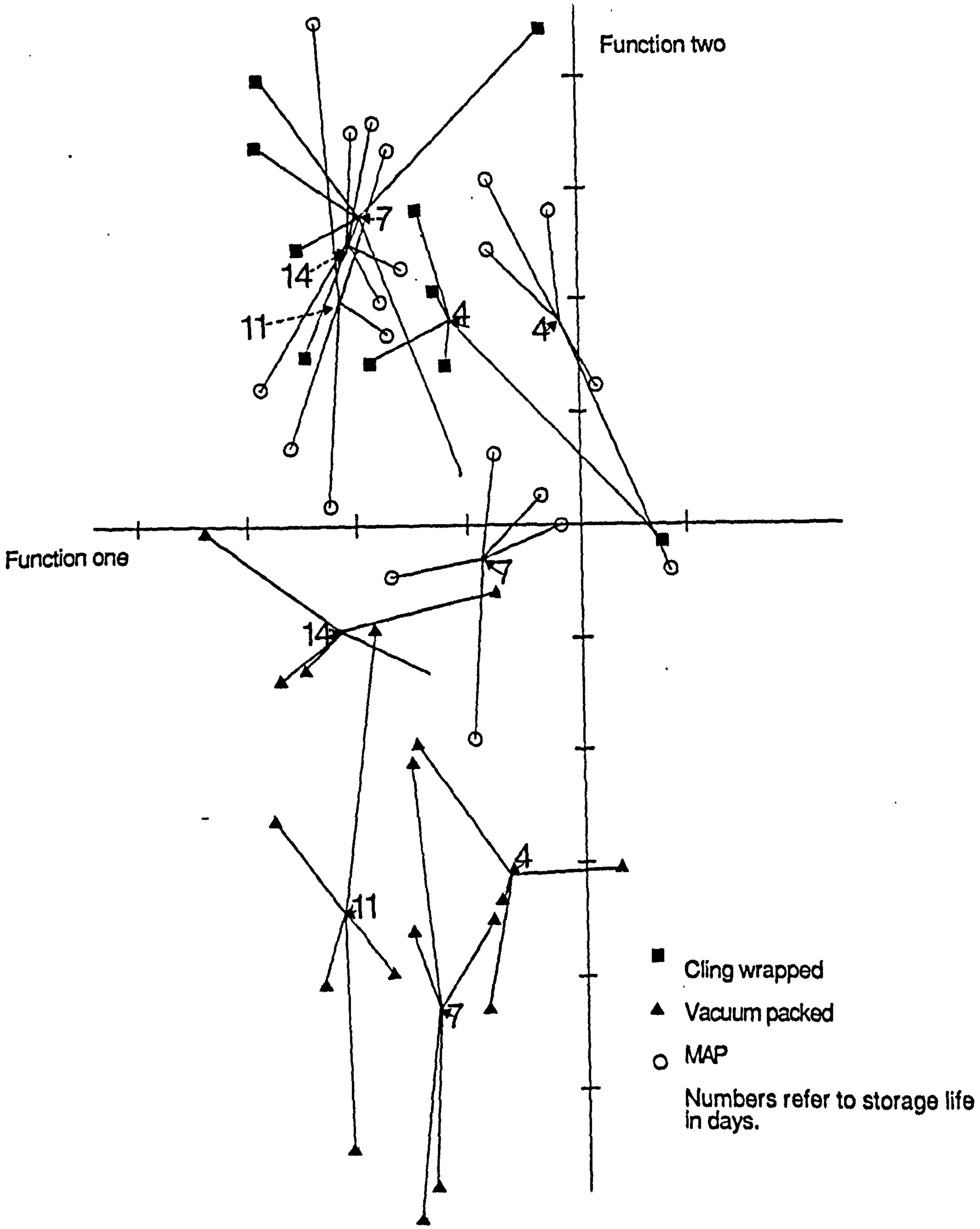
The sensory attributes with large negative weightings on function 2 included bland odour, compact appearance of meat fibres, first bite and fried chicken odour. Thus low scores on these attributes characterized the vacuum packed drumsticks. Degree of shrivelling and rancid flavour had high positive weighting coefficients on this function and so were associated with the cling wrapped samples and to a lesser extent the MAP drumsticks.

Discriminant function 3 contributed to the separation of packaging types by pulling the cling wrapped drumsticks further from the MAP samples (Figure 7.8).

Certain of these results confirm those of the univariate analyses; the greater effect of storage life in comparison with packaging on the sensory attributes; the difference between MAP, vacuum and cling wrapped drumsticks.

Previous investigators have used the mean scores for each sample as the input for multivariate data reduction techniques, such as factor analysis (principal component analysis) (Horsfield and Taylor, 1976; Frijters, 1976). Consequently the variation around the mean score in the reduced dimensional space could not be examined. In contrast this study allowed the mean replication discriminant scores for each sample to be calculated and plotted. Areas of overlap between sample groups could then be examined, examples are shown in Figure 7.9.

Figure 7.9 The mean replication discriminant scores of chicken drumsticks plotted on discriminant functions one and two.



Where a mean replication discriminant score was relatively distant from the group mean, the discriminant scores for that replication were studied in search of scores causing the deviation. For example, the MAP drumsticks stored for 4 days had a group mean discriminant score on discriminant function 2 of 0.47. All the replication mean scores with the exception of one, which was -0.10 had values greater than 0.47. The cause of the negative mean replication score was the scores of judges 3, 4 and 5 whose scores during this replication were -0.75, -0.58 and -0.47 respectively. These scores were closer to the vacuum packed samples than the MAP ones. However, despite these extreme values this replication mean score did not overlap with other groups.

All other outlying replication mean scores were examined, but no one judge or replication consistently yielded extreme values and therefore all data was retained.

Overlaps between sample groups replication mean scores were then considered. There was considerable overlap between the MAP samples stored for 11 and 14 days and the cling wrapped drumsticks stored for 4 and 7 days. The vacuum packed samples stored for 14 days also appeared to overlap with other vacuum packed samples. It was decided to repeat the SDA with fewer sample groups, with the aim of achieving better separation between groups. In the absence of the samples stored for 14 days (MAP and vacuum packed) the cumulative variance for the first three discriminant functions increased from 95.04 to 96.19%, with the greatest gain on the second discriminant function (Table 7.5). In the absence of the samples stored for 14 days, surface brightness and degree of chewing were no longer included in the analysis.

Although classification of unknown samples was not an objective of this study, the use of the discriminant functions as classification tools was examined. All the samples were classified as if their group membership was unknown. The percent of correct classifications made by the different discriminant functions are shown in Table 7.7. It

may be seen that the best total classification result (44.61%) was obtained when the data for the samples stored for 14 days was not included and the fresh samples were combined into one group. Thus fewer than one in two unknown samples could be correctly classified. The MAP samples stored for 7 and 11 days presented most difficulty in correct classification, while the vacuum packed samples had the highest percent of correct classifications. The reason for this was because they overlapped the stimulus space of other groups as discussed previously and shown in Figure 7.9.

Johnson and Wichern (1982) pointed out that discriminant analysis may achieve significant separation of groups, but efficient classification may still not be possible.

Table 7.7. The percentage of known groups correctly classified by the discriminant functions from different stepwise discriminant analyses.

Sample group		A	B	C	D
Vacuum packed		%	%	%	%
	0	45.0	85.2	37.5	86.7
	4	25.0	27.5	37.5	27.5
	7	37.5	40.0	47.5	37.5
	11	25.0	25.0	35.0	30.0
	14	7.5	25.0	-	-
MAP					
	0	22.5	-	27.5	-
	4	50.0	50.0	50.0	52.5
	7	5.0	7.5	10.0	7.5
	11	10.0	7.5	40.0	25.0
	14	20.0	22.5	-	-
Cling wrapped					
	0	33.3	-	52.1	-
	4	10.4	8.3	25.0	16.7
	7	33.3	33.3	31.2	33.3
	Total	25.0	37.50	31.25	44.6

A: All 13 groups.
B: 11 groups (3 groups of fresh samples combined into 1 group)
C: 11 groups (samples stored for 14 days not included)
D: 9 groups (fresh samples combined into 1 group and samples stored of 14 days not included).

7.4.2. Stepwise discriminant analysis of chicken a la king

This procedure has been described in section 6.4.3.2.1. The eigenvalues and percent of variance explained for each of the discriminant functions retained in the analyses are shown in Table 7.8.

Table 7.8. The eigenvalues and percentage variance of the discriminant functions retained in the SDA of chicken a la king.

	Function Number	Group composition: All 13 groups	Group composition: 11 groups (fresh samples combined in one group)
Eigenvalues	1	1.0	0.95
	2	0.23	0.22
	3		0.09
% Variance	1	64.81	65.88
	2	15.07	15.44
	3		6.56
% Cumulative variance		79.83	87.88

Two SDA's were undertaken, the first with all 13 sample groups which included the 3 separate groups of fresh samples and second, 11 groups where the fresh samples were combined into one group. The SDA summary tables for each analyses produced by SPSS are shown in Appendix 9.

In the first analysis the chi-squared value was significant for the first two discriminant functions and hence only two discriminant functions were retained, whereas it was significant for the first three functions where the fresh samples were combined into one group resulting in a greater recovery of information as shown in the cumulative variance figures (Table 7.8). The same sensory attributes were selected in each analysis and included the 8 appearance

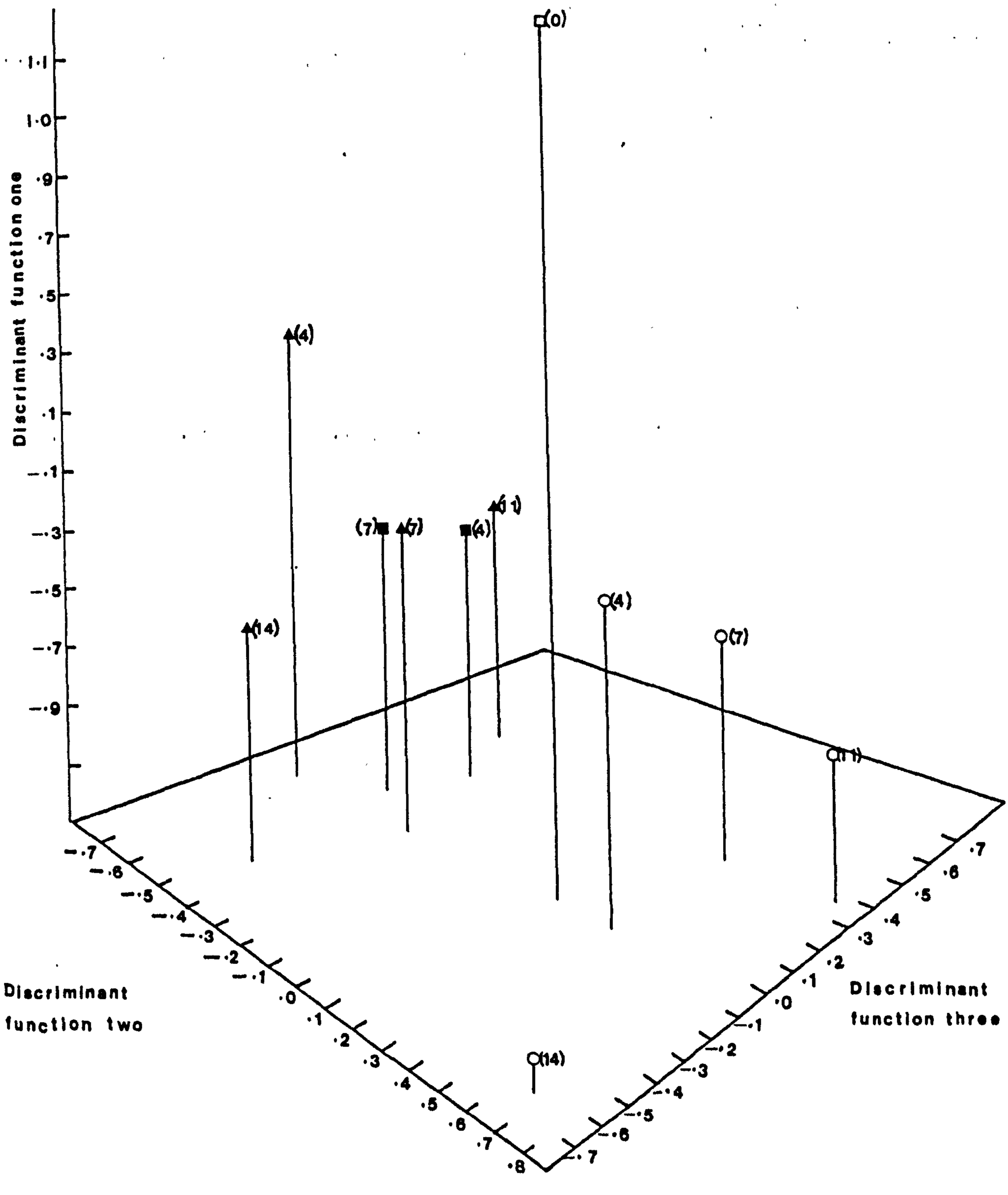
attributes as well as pea texture, chicken flavour and stale flavour. The eigenvalues for the discriminant functions were lower than those found in the SDA of chicken drumsticks (Table 7.7). Consequently the percent of cumulative variance explained by the retained discriminant functions was also reduced from 95.04% for chicken drumstick to 87.88% for chicken a la king (fresh samples combined into one group).

Plots of the group centroids are shown in Figure 7.10. Discriminant function 1 separated the MAP samples from the day 0 samples in order of increasing storage life. To a lesser extent this applies to the vacuum packed samples. Both tne cling wrapped samples stored for 4 and 7 days had similar scores on discriminant function 1 as the vacuum samples stored for 11 and 14 days and the MAP samples stored for 7 days.

When compared with the plot of group centroids of the chicken drumsticks it may be seen that the separation of groups is not as great and the relationship between sensory attributes and experimental variables (packaging and storage life) is less clear. The discriminant coefficients for each of the retained sensory attributes are shown in Table 7.9. On ciscriminant function 1 shade of pea colour is the most important variable, followed by depth of colour and gelatinous appearance of the sauce. On function two surface oil, pea colour and granular appearance all have high weightings. Thus packaging and storage life have very little or no effect on the sensory quality of chicken meat in chicken a la king, which confirms the results of the univariate analysis.

Figure 7.10 Mean discriminant scores* of chicken a la King plotted on the first three discriminant functions.

* SDA of 11 samples, 0 days standards combined in one group.



*Numbers in parentheses are storage life in days

Table 7.9 The discriminant function coefficients of the retained sensory attributes in the SDA of chicken a la king.

Sensory attribute	Discriminant functions 1	2	3
Granular	-0.03	-0.38	0.39
Gelatinous	-0.31	-0.03	-0.14
Depth of colour	0.37	0.10	-0.53
Sauce coating	0.25	0.33	0.59
Meat appearance	0.21	-0.13	0.14
Shade of pea colour	-0.56	0.60	0.09
Range of pea colour	-0.03	-0.25	0.20
Surface oil	0.25	0.62	0.02
Pea texture	-0.03	0.26	-0.41
Stale flavour	0.02	-0.20	-0.39
Chicken flavour	0.10	-0.16	0.26

7.5 Conclusions

In the three way ANOVA for each model and product, the effects of replication and judge and interactions between the major effects were rarely significant, which indicates the success of the experimental design in eliminating experimental error.

The effect of packaging and storage life varied with the two cooked menu items examined in this study. Storage life had a significant ($P<0.05$) effect on all the sensory attributes of chicken drumsticks and especially affected flavour. In contrast just over half of the sensory attributes of chicken a la king were significantly affected by storage life and most of those related to appearance. For both products the greatest change in any attribute occurred between 0 and 4 days.

The effect of packaging on sensory quality was also less in chicken a la king when compared with chicken drumsticks. The reason for this was because the chemical reactions causing flavour changes in chicken drumsticks (fat oxidation) were influenced by the experimental variable storage

atmosphere, which will have had little effect on retrogradation and pheophytinization, which were the major sensory changes occurring in chicken a la king.

The comparison of these two menu items emphasizes the importance of the minor components of a product in influencing the overall sensory quality. For example in the SDA of chicken a la king the single best discriminating variable was the apparently trivial character of pea colour. If peas were removed from the product or this colour reaction was prevented by means of elevating the pH, then the effect of storage life on sensory quality would be substantially reduced.

The success of the experimental design and the power of multivariate statistical techniques were demonstrated in the stepwise discriminant analyses of chicken drumsticks. The experimental variables, packaging and storage life, whose levels were not specified in these analyses, were represented by three discriminant functions, one of which managed to order the drumsticks according to the levels of storage life, while simultaneously indicating the sensory attributes which contributed to this differentiation. The multivariate techniques confirmed the results of the univariate analyses and were extremely useful in presenting the results of a large complex data set in a single three dimensional plot. They also allowed the size of the data set to be substantially reduced with limited loss of information for subsequent analysis.

The sensory experiments have allowed the major sensory changes occurring in the two products to be quantified in a reliable manner. But it should be established of what use this is to the catering or vending industry. The most useful results are that the sensory changes in cling wrapped chicken drumsticks occurred at a faster rate than in the MAP or vacuum packed samples, thus the use of these packaging methods may potentially improve the organoleptic quality of cooked menu items. However, MAP techniques may increase the

rate of certain degradative changes, such as pheophytinization and so the application of this technique will be limited to certain product types.

However, whether this apparent improvement in product quality brought about by MAP or vacuum packing is of significance to the consumer is undetermined. The consumer may not be aware of the significant differences in product quality that were detected by trained judges under experimental conditions or the consumer may not actually prefer the fresh product. Most people are accustomed to eating cooked meats that have been refrigerated for at least 24 hours, during which time warmed over flavours would have developed, thus it is possible that these flavours are considered as desirable attributes of cold cooked meats. For a more useful application of these results to industry a consumer acceptability trial of the chicken drumsticks was undertaken and is described in the next chapter.

CHAPTER 8

THE EFFECT OF PACKAGING AND STORAGE LIFE ON THE CONSUMER ACCEPTABILITY OF COOKED CHICKEN DRUMSTICKS.

8.1. Introduction

Storage life and packaging both significantly effect the sensory quality of cooked menu items (Chapter 7). MAP and vacuum packaging tend to inhibit the flavour changes occurring in cling wrapped chicken drumsticks during refrigerated storage, and vacuum packaging has a distinctive effect on their textural quality. The objective of the consumer acceptability study described below therefore was to establish whether these organoleptic differences were of significance to the consumer and establisn a model, which would allow the sensory quality resulting from a given combination of storage time and packaging to be predicted.

Previous sensory experiments in this study had shown distinct differences between judges use of scales and also their perception of sensory attributes. For example certain judges were better able to distinguish differences between cling wrapped samples than between MAP or vacuum packed samples and vice versa (Chapter 6, Section 6.4.2.). It is therefore probable that similar differences exist within the consumer population. Perceptual differences may also apply to subjective opinions of acceptability and it was therefore decided to examine the results of individual consumers by means of multidimensional scaling, as well as combining the results for all consumers using multiple regression.

8.2. Methods

8.2.1. Consumer panel procedures

Two separate consumer trials were undertaken, with members of staff at Barclays International, Poole and also at Poole General Hospital.

The chicken drumsticks were prepared and packaged according to methods described in Chapter 2, so that on the day of each trial there were 100 samples of each of the following; cling wrapped chicken drumsticks stored for 4 and 7 days, vacuum packed drumsticks stored for 4, 7 and 11 days, MAP drumsticks stored for 4, 7 and 11 days and freshly prepared drumsticks.

Prior to each trial the forthcoming acceptability studies were advertised at the two locations and all employees were invited to take part by means of posters and display tents in the staff dining area. A short background questionnaire on age, sex, job, frequency of use of staff dining facilities and vending machines and frequency of chicken consumption was also made available for prospective subjects to complete before the samples were given. A copy of this questionnaire is shown in Appendix 10. Individual booths were erected by means of screens in the staff dining area and were lit by a combination of natural and strip lighting. At Barclays the trial took place between 11:30am and 1:30 pm and at the hospital between 10:00 am and 1:30 pm.

Instructors, who were either staff or students from the Dorset Institute of Higher Education, assisted volunteers by explaining what the trial involved and by administering the appropriate samples and forms. Each booth was manned by an instructor thus ensuring personal attention for each volunteer at all times. Twenty five instructors were trained prior to the trials, in order to standardize their

procedures. Guidelines on standard procedures are included in Appendix 10.

Each volunteer assessed 9 chicken drumsticks, which were presented on three consecutive trays of three samples each. The samples were labelled with a three figure random number. The presentation order is shown in Table 8.1.

Table 8.1 The presentation order of chicken drumsticks in the acceptability trial.

					Packaging:	Age:
Tray one	1	4	7	1:	Day 0 standards	0
				2:	Vacuum packed	4
Tray two	2	5	8	3:	Vacuum packed	7
				4:	Vacuum packed	11
Tray three	3	6	9	5:	MAP	4
				6:	MAP	7
				7:	MAP	11
				8:	Cling wrapped	4
				9:	Cling wrapped	7

A percentage of the subjects received two similar trays of samples and one different tray, which allowed the consistency of scoring of the population to be tested.

The presentation order of the samples was partly dictated by the number of samples under examination. The difficulty of the test encountered by subjects would increase with the number of samples to be evaluated at any one time. But unless samples are experienced together comparisons may not be easily made. This is because the use of a scoring scale by a non expert is largely dependent on the range of sample attributes before them. However, it is extremely difficult for an individual to accurately compare and score 11 samples at once, which was the original number of samples in the sensory study. Neither is 11 divisible, thus if samples were split into smaller groups for evaluation at least one sample would be duplicated amongst groups. In order to facilitate the design of the experiment the number of samples were reduced to nine which could be presented in three groups of three. This was considered the best

compromise as two of the samples represented a complete storage life level (MAP and vacuum packed products stored for either 11 or 14 days) and also because the exclusion of the drumsticks stored for 14 days from the sensory profile of chicken drumsticks in the stepwise discriminant analysis had resulted in an improvement in the overall analysis (see Section 7.4.1., Chapter 7) by increasing the percentage variance contained in the first three discriminant functions.

It was therefore decided to exclude the two samples stored for 14 days from the study. The composition of the groups of three samples was decided by randomly allocating the nine samples to one of the nine positions. Standardizing the group composition and presentation order of the samples greatly facilitated the preparation of trays of samples at the two sites. For example at Barclays 900 packaged chicken drumsticks had to be placed in any one of nine labelled individual containers and placed in any one of three positions on any one of three trays all in the space of two hours. In addition to this replicated trays had to be arranged.

The disadvantage of this design was that it was not possible to test for presentation order effects. In other words it was not known whether the samples would be scored in a similar fashion if presented in a different order. The logistics of an experiment designed to test for such an effect were beyond the resources available.

Each subject initially scored each group of three samples on an unstructured scale anchored at either end by like extremely and dislike extremely (low score; like extremely). On completion of this task, all 9 samples which remained in front of the volunteer were scored on a single scale. Therefore, each sample was assessed twice, first as a member of a group of three and second as a group of nine drumsticks. A copy of the form is shown in Appendix 10. At the end of the tasting session each volunteer received a token for a hot drink and a chocolate biscuit.

8.2.2. Analysis

All judgements were transformed into scores by placing a ruler against the 15cm scoring line. The results from the two consumer populations were analyzed independently. The scores of the samples presented in threes were analysed separately from the scores of all nine samples scored on one scale. The effect of replications was examined by means of two way ANOVA by score order (replication) and sample type.

Pearsons correlation coefficients between the acceptability scores for each samples and the characteristics of the volunteers were calculated. The characteristics of the population were examined by calculating the frequency of occurrence of pairs of attribute and associated chi-squared values, which indicated the significance of association between attributes. Job title was used to classify volunteers into job categories corresponding to minor groups in the Classification of occupations and directory of occupational titles (Department of Employment, 1972).

The mean acceptability scores were related to the three discriminant scores of each chicken drumstick and the experimental variables, packaging and storage life, using multiple regression (Nie et al., 1975). The individual acceptability scores were related to the discriminant scores using Carrolls (1972) Prefmap analysis (Schiffman et al., 1981).

8.3. Results and discussion

The consumer populations of interest were those who represented the market for chilled food vending. As no actual chilled food vending systems were operating in the area potential food vending markets were considered the next most appropriate consumer population. Industrial and hospital

catering were often associated with chilled food vending in the review of the vending industry described in Chapter 3 and therefore two local sites were approached, both of which used vending machines to sell hot and cold drinks and long life snacks and confectionery and offered a staff restaurant facility. At Barclays a total of 92 subjects volunteered, 6 of whom replicated judgments. At the hospital 80 subjects volunteered of whom 9 replicated their judgments.

By carrying out the preference tests in booths rather than allowing the consumer to purchase and consume the product in the normal manner from a CFVM this study was essentially a "hall" test rather than a true consumer test. According to Booth (1981) the acceptance of a food for an individual is a dynamic process, in which the relationship between the food and the person changes from moment to moment and depends on the situation in which the person faces the food. It therefore should not be assumed that preferences for a food are static or context free. In particular, first impressions of a food are liable to change due to sensory adaptation and habituation (Koster, 1981).

8.3.1. Characteristics of the sample population

The number of volunteers correctly completing the background questionnaire was 73 at the hospital and 86 at Barclays International (7 subjects at Barclays did not give their job title). A summary of the results is given in Table 8.2. and the chi-squared values between pairs of characteristics in Table 8.3.

Table 8.2. A summary of the characteristics of the sample populations (Barclays; n=86, Poole hospital; n=73).

	Barclays %	Poole hospital %
Sex		
Male	54.7	32.9
Female	45.3	67.1
Age		
< 25	31.4	30.1
25 - <50	59.3	53.4
>50	9.3	16.4
Occupation*		
1	2.5	-
2	21.5	2.7
3	-	49.3
4	1.4	6.8
5	7.6	8.2
6	-	1.4
7	64.5	9.6
9	1.4	1.4
10	1.4	19.2
11	-	1.4
Number of hours worked		
< 20	7.0	9.6
20 - < 35	19.8	12.3
>35	73.3	78.1
Use of staff restaurant		
Several times a week	90.7	65.8
Several times a month	3.5	9.6
Several times a year	5.8	11.0
Never	-	13.7
Frequency of eating chicken		
Several times a week	20.9	31.5
Several times a month	53.5	63.0
Several times a year	23.3	5.5
Never	2.3	-
Frequency of use of chilled food vending machines		
Several times a week	-	-
Several times a month	3.5	5.5
Several times a year	18.6	31.5
Never	77.9	63.0

* for occupation n=79 at Barclays

Occupation groups (Department of Employment, 1972):

1 Managerial occupations (general management)
2 Professional and related occupations supporting management and administration
3 Professional and related occupations in education, welfare and health.
4 Literary, artistic and sports occupations.
5 Professional and related occupations in science, engineering, technology and similar fields.
6 Managerial occupations (excluding general management).
7 Clerical and related occupations.
9 Security and protective service occupations.
10 Catering, cleaning and other personal service occupations
11 Farm, fishing and related occupations.

The hypothesis that the two populations represented potential markets for chilled food vending was confirmed by the results of the survey; 22.1% of the sample at Barclays and 37% of the hospital subjects purchased cooked foods from CFVM's at least several times a year in comparison with 2% of the general population (Section 1.2, Chapter 1).

Table 8.3 The significance levels of chi-squared values for pairs of the population characteristics.

Population characteristics		1	2	3	4	5	6	7
Barclays subjects								
1	Sex		0.03	0.02	0.02	0.88	0.21	0.37
2	Age of volunteer			0.72	0.01	0.91	0.05	0.04
3	Occupation				0.88	0.99	0.11	0.98
4	Hours worked					0.21	0.72	0.85
5	Use of restaurant						0.74	0.64
6	Chicken consumption							
7	Use of vending machines.							
Poole subjects		1	2	3	4	5	6	7
1	Sex		0.32	0.01	0.04	0.54	0.07	0.11
2	Age of volunteer			0.03	0.05	0.30	0.47	0.15
3	Occupation				0.60	0.00	0.22	0.04
4	Hours worked					0.06	0.95	0.32
5	Use of restaurant						0.59	0.68
6	Chicken consumption							0.45
7	Use of vending machines.							

All volunteers were employees at either establishment. At Barclays more men (54.7%) than women (45.3%) took part in the trial whereas at Poole hospital 67.1% of the volunteers were women. This reflected the higher proportion of women working at the hospital. At Barclays there was a significant association between sex and age of the volunteers; a higher percent of women (17.9% as compared to 2.1% of men) were over 50 and 38.3% of men were below 25 as compared to 23.1% of women, thus the women tended to be older.

Not surprisingly, at both the hospital and Barclays sex was also significantly associated with the number of hours worked; 85.1% of men at Barclays and 96.2% of men at the hospital worked more than 35 hours a week, whereas only 59% of women working at Barclays and 72.2% of women working at the hospital did. Sex was also significantly associated with an individuals occupation. At Barclays 15 of the individuals in occupations classified as professional and related occupations supporting management and administration (group 2) (predominantly computer programmers) were men and only two were women. At Poole hospital 29 individuals classified under professional and related occupations in education, welfare and health (predominantly nursing occupations) were women and 7 were men. Group 7 (clerical are related occupations) at Poole hospital was exclusively women (100%).

The occupations of the two sample populations reflected the nature of the major activity of each organization, namely clerical and computing work at Barclays and health care at Poole hospital. Occupation is one of the indicators of social class, but on its own is insufficient to categorize people into social class groupings.

Three out of ten volunteers at both sites were less than 25 years of age, whereas only approximately one in ten were over 50. At both sites the subjects age was significantly ($P<0.05$) associated with the number of hours a week they worked. The number of hours worked tended to decrease with increasing age. At Poole Hospital age was also associated with occupation, the most probable cause of this was the high proportion of nurses (47.2%) below 25.

At Barclays age was associated with frequency of use of vending machines; 40% of volunteers aged below 25 had bought food from vending machines at least several times a year, whereas for people aged between 25 and 50 the figure was 17.6% and none of the volunteers over 50 had used such machines. This indicates the youthful nature of the market for vended products. At Poole hospital the frequency of use

of vending machines was not significantly associated with tne age of volunteers but was significantly associated with their occupation. Group 5 (professional and related occupations in science, engineering, technology and similar fields) and 10 (catering, cleaning and other personal service occupations) were the highest users and members of group 7 (clerical and related occupations) the least frequent.

8.3.2. Reproducibility of results

It was considered important to sacrifice a small proportion of potential subject scores in order to test how consistent their scoring patterns were.

Nine of the 80 volunteers at Poole hospital and 6 of the volunteers at Barclays assessed the same three samples in the same position twice. To determine whether the volunteers were scoring the samples consistently, 2 way ANOVA by score order (first or second tray) and sample type was undertaken. Where the difference between the sample types was greater than the difference between scores for the same sample (score order) then the volunteers were sufficiently reproducing their results to allow differences between samples to be meaningful. The results of the ANOVA are summarized in Table 8.4.

Only one group of 3 volunteers at Barclays were unable to reproduce their results, in that the F values for score order were greater than those for sample differences. This group were scoring the cling wrapped, MAP and vacuum packed samples stored for 4 days, which were less dissimilar than some of the other groups of three samples scored in this test. For example, the mean discriminant score of the day 0 product and the MAP and vacuum packed product stored for 11 days are further apart from each other in the 3 dimensional plot of discriminant functions shown in Figure 7, than the samples stored for 4 days. Consequently the former group of samples had a higher F value ($P<0.001$) for differences

between sample types than the latter groups of samples (Table 8.4). Therefore the reduced perceptual differences between the samples stored for 4 days probably accounted for the greater difficulty subjects had in consistently scoring the drumsticks.

From the results of this test it was concluded that the other 12 volunteers were consistent in their scoring and that subsequently the credibility of the results would be increased. Unfortunately these results cannot be compared with other similar investigations reported in the literature as no other acceptability studies testing reproducibility of results were found.

Table 8.4 F values for two way ANOVA by score order and sample type to determine the ability of volunteers to reproduce results.

Samples	No of subjects		Score order	Sample type	Interaction
Barclays					
1, 4, 7,	3	(i)	0.11	2.32	1.73
		(ii)	0.05	2.23	0.13
2, 5, 8,	3	(i)	0.69	0.09	2.43
		(ii)	0.46	0.13	2.24
Poole hospital					
3, 6, 9,	4	(i)	0.00	2.06	0.37
		(ii)	0.20	3.30	0.26
1, 4, 7,	5	(i)	0.13	10.05*	0.59
		(ii)	0.61	10.56*	0.52

* P<0.001
(i) ANOVA on scores of samples presented in groups of three.
(ii) ANOVA on scores of all 9 samples on one scale.

8.3.3. The results of the trial at Barclays.

A summary of the descriptive statistics of the acceptability scores from subjects at Barclays is shown in

Table 8.5. The mean scores for Barclays subjects of each sample are plotted in Figure 8.1.

The results of the descriptive analyses of subject scores for acceptability are discussed in the following two sections, but will be summarized here. On average, subjects preferred the day 0 drumsticks and found the cling wrapped chicken drumstick stored for 7 days to be least preferred. The largest difference in mean acceptability score was found between the day 0 sample and stored samples, which agrees with the results of the sensory profile study. For products of like storage life, the MAP drumsticks were preferred to the vacuum packed samples. More variation in scores was apparent in the hospital subjects results, where the effect of storage life on acceptability score was dependent on the packaging category (significant interaction effect, $P<0.05$).

Table 8.5 Descriptive statistics of the acceptability scores of chicken drumsticks scored by the subjects at Barclays.

Samples scored by subjects in groups of three

	Mean	S.E.	S.D.	Range	Kurt -osis	Skew -ness
0 days	4.93	.310	2.85	12.7	-.697	.407
Vac 4	6.41	.339	3.12	13.6	-.545	.124
Vac 7	7.50	.377	3.47	14.6	-.375	.246
Vac 11	7.87	.336	3.09	14.2	-.438	-.176
Map 4	6.71	.393	3.62	14.1	-.548	.368
Map 7	6.69	.414	3.82	14.5	-.614	.374
Map 11	6.71	.398	3.67	14.4	-.363	.573
Cli 4	8.33	.439	4.05	14.4	-1.10	-.096
Cli 7	9.15	.412	3.80	14.4	-.554	-.44

x=3.49

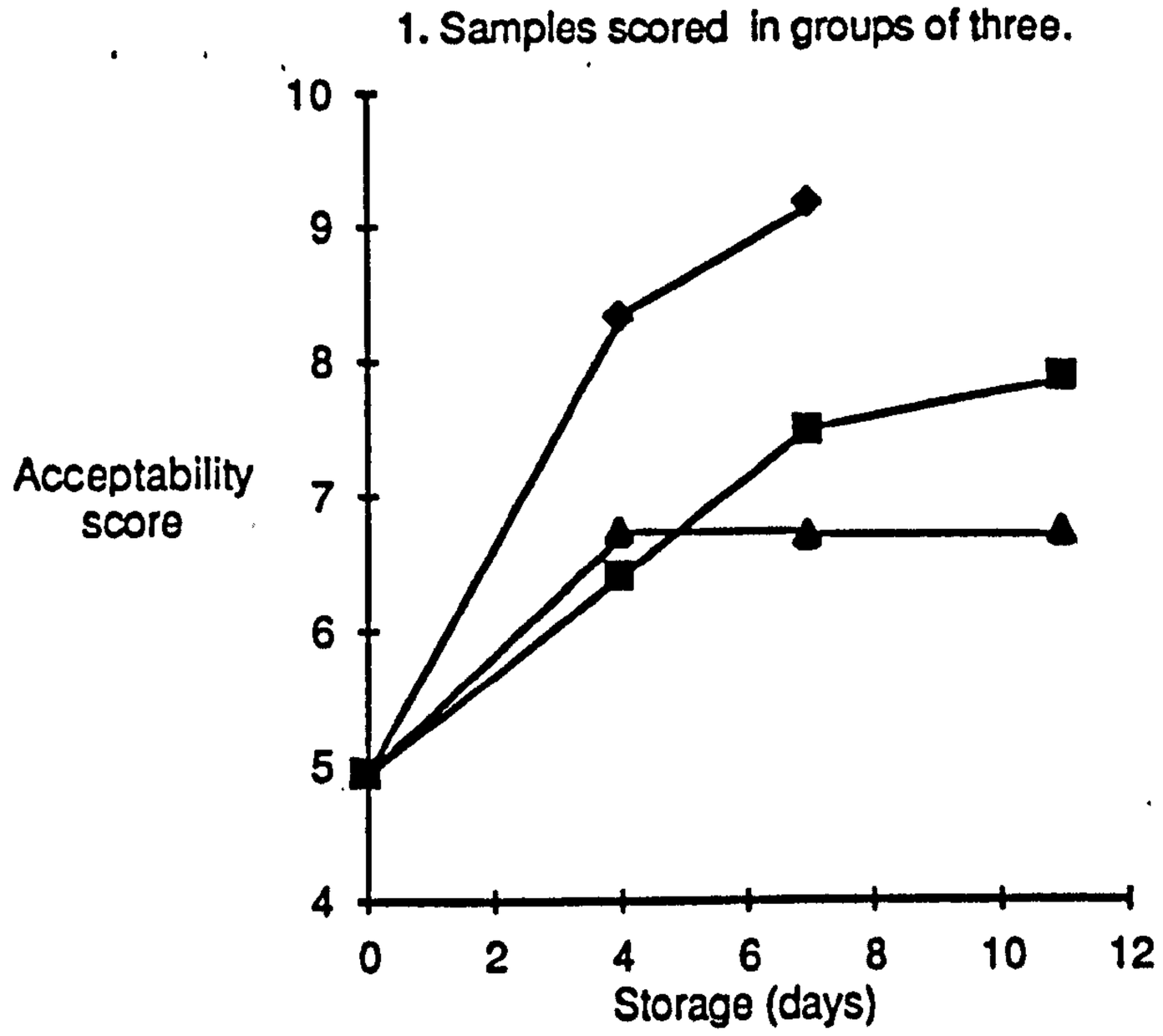
Samples scored by subjects in one group of nine

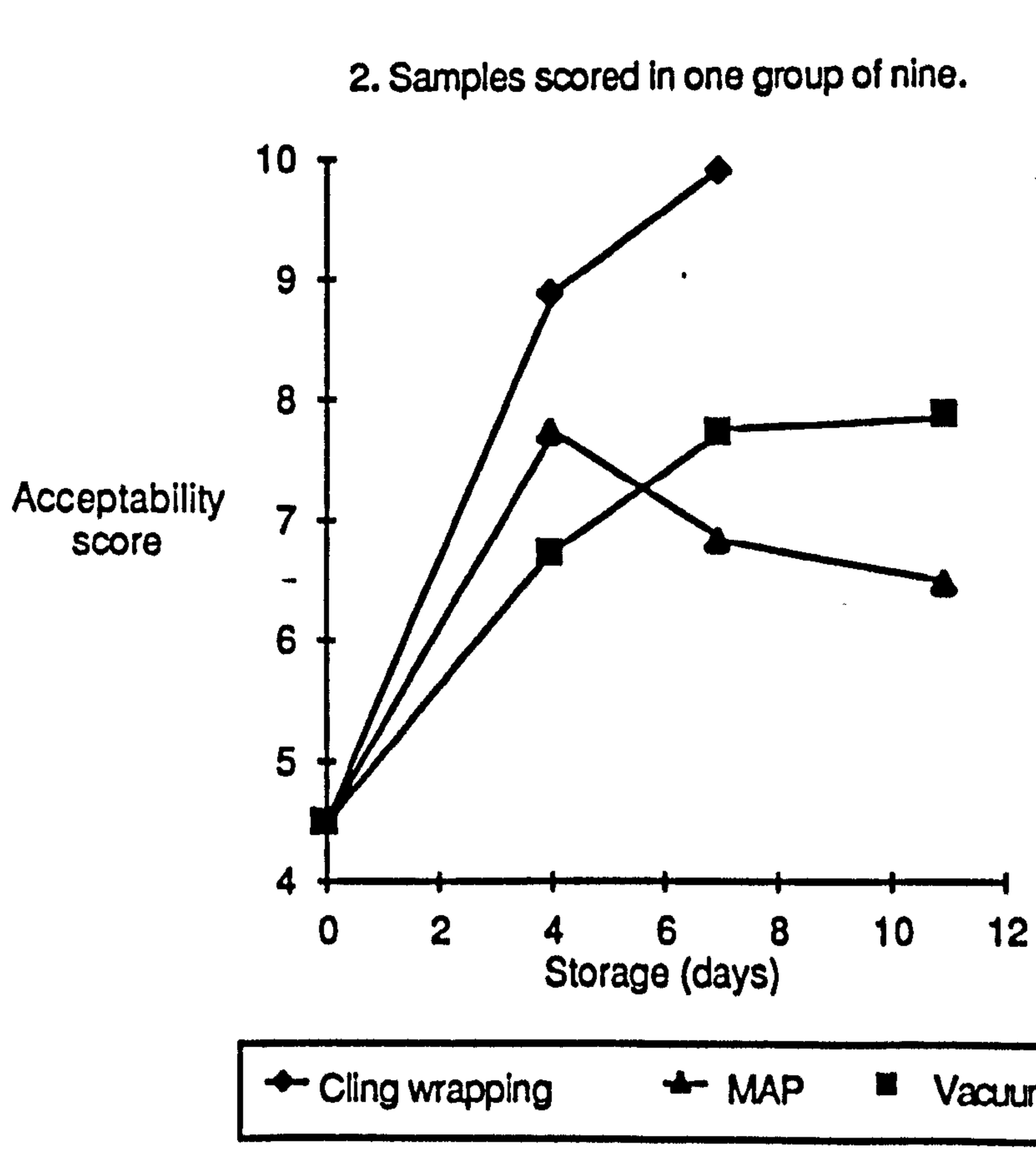
	Mean	S.E.	S.D.	Range	Kurt- osis	Skew- ness
0 days	4.49	.328	2.80	11.4	-.708	.472
Vac 4	6.73	.372	3.17	14.4	-.428	-.134
Vac 7	7.72	.388	3.32	14.8	-.134	-.024
Vac 11	7.83	.368	3.14	13.8	-.223	-.479
Map 4	7.17	.448	3.82	14.2	-.964	.209
Map 7	6.80	.445	3.78	14.3	-.659	.385
Map 11	6.44	.456	3.90	14.6	-.675	.438
Cli 4	8.87	.458	3.91	13.9	-1.15	-.138
Cli 7	9.91	.428	3.65	14.2	-.329	-.580

x=3.49

S.E. : standard error
S.D. : standard deviation

Figure 8.1. The acceptability mean scores of chicken drumsticks scored by subjects at Barclays.

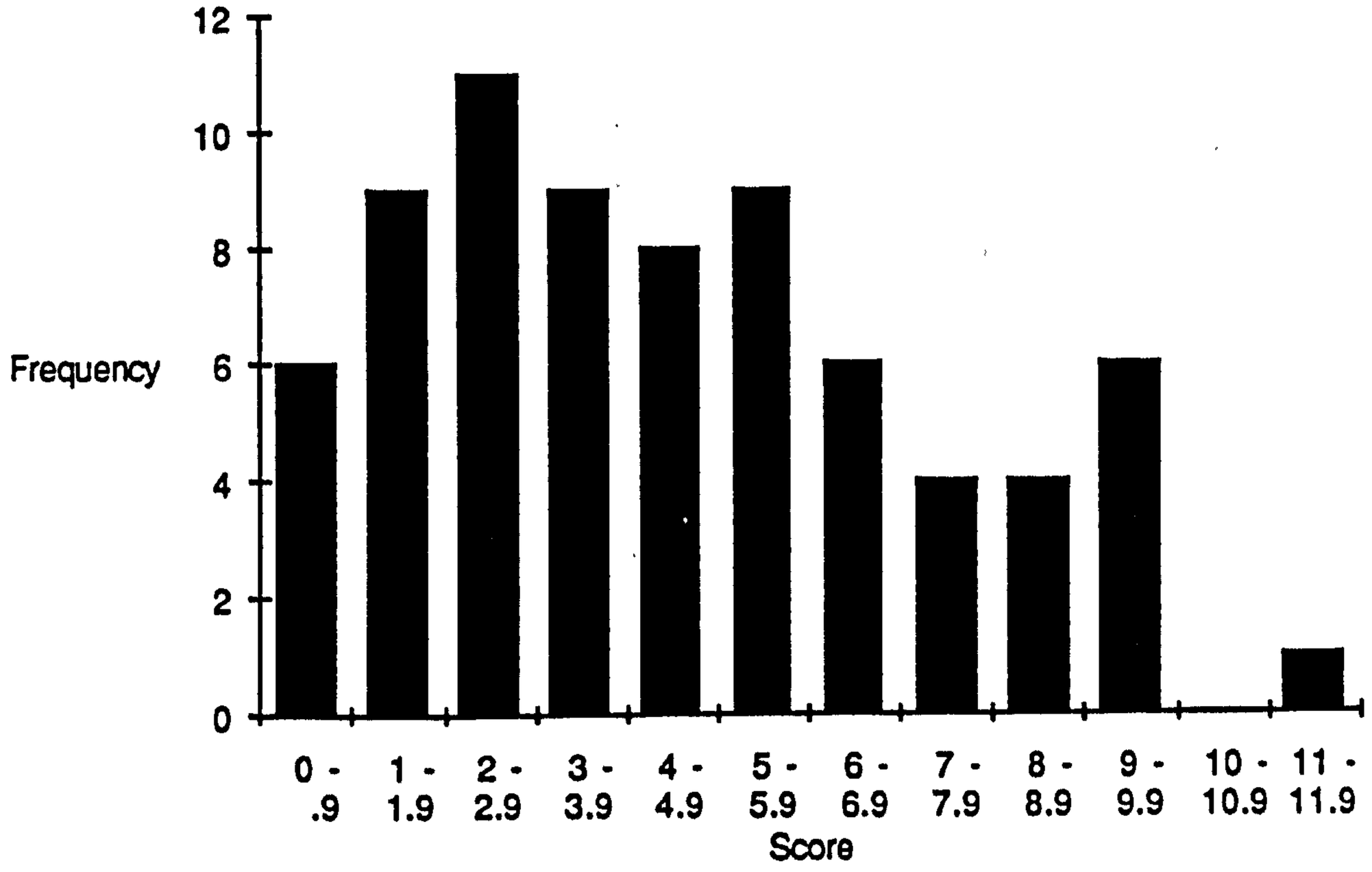




The scores of chicken drumsticks scored in groups of threes were very similar to those when all nine were scored together on one scale (r=0.99) and the order of preference did not change. When the mean scores were ranked the most preferred drumsticks was the day 0 sample, followed by the vacuum packed sample stored for 4 days, followed by the three MAP samples, followed by the vacuum packed sample stored for 7 days, then the vacuum packed sample stored for 11 days and lastly the cling wrapped drumsticks in order of storage life (the oldest product being least preferred) (Figure 8.1).

The range of scores around each mean invariably covered most of the scale, which indicates that between subjects there was a large variation in the use of scales and or individual subjects widely differed in their opinions. Kurtosis and skewness are indicative of departures of the frequency distribution from normality. For a normal distribution the kurtosis ratio has a value of 3. A value of less than 3, which was found throughout this study, indicates that the distribution curve has a flatter top than the normal distribution, which would confirm the wide range in scores that were found. Skewness is a measure of the shape of the distribution curve; a positive value means that low values of x are bunched close to the mean and high values of x extend far above the mean and vice versa for a negative value. The size of the skewness value associated with the mean of each sample decreased with order of preference (the day 0 sample had the highest positive value for skewness and the cling wrapped sample stored for 7 days has the highest negative value for skewness). This was due to an inherent problem in the use of scoring scales. When the mean falls at one end of the scale, the distribution will undoubtedly be squashed on one side as shown in the plot of scores for the day 0 sample in Figure 8.2. giving a lopsided or skew distribution. The values for standard errors, kurtosis and skewness were similar for both scoring methods (Table 8.5).

Figure 8.2. The frequency distribution of scores for the acceptability of fresh chicken drumsticks (n=86).



8.3.4. The results of the trial at Poole hospital.

A summary of the descriptive statistics of the hospital subject scores is shown in Table 8.6 and the mean scores are plotted against storage life in Figure 8.3.

The day 0 sample had the lowest mean score indicating it was on average the most preferred sample, followed by the MAP sample stored for 11 days and then the MAP samples stored for 7 days. The high ranking of the mean score of the MAP sample stored for 11 days agrees with the result at Barclays (all samples scored together).

Table 8.6 Descriptive statistics of the acceptability scores of chicken drumsticks scored by subjects at Poole hospital.

Samples scored by subjects in groups of three

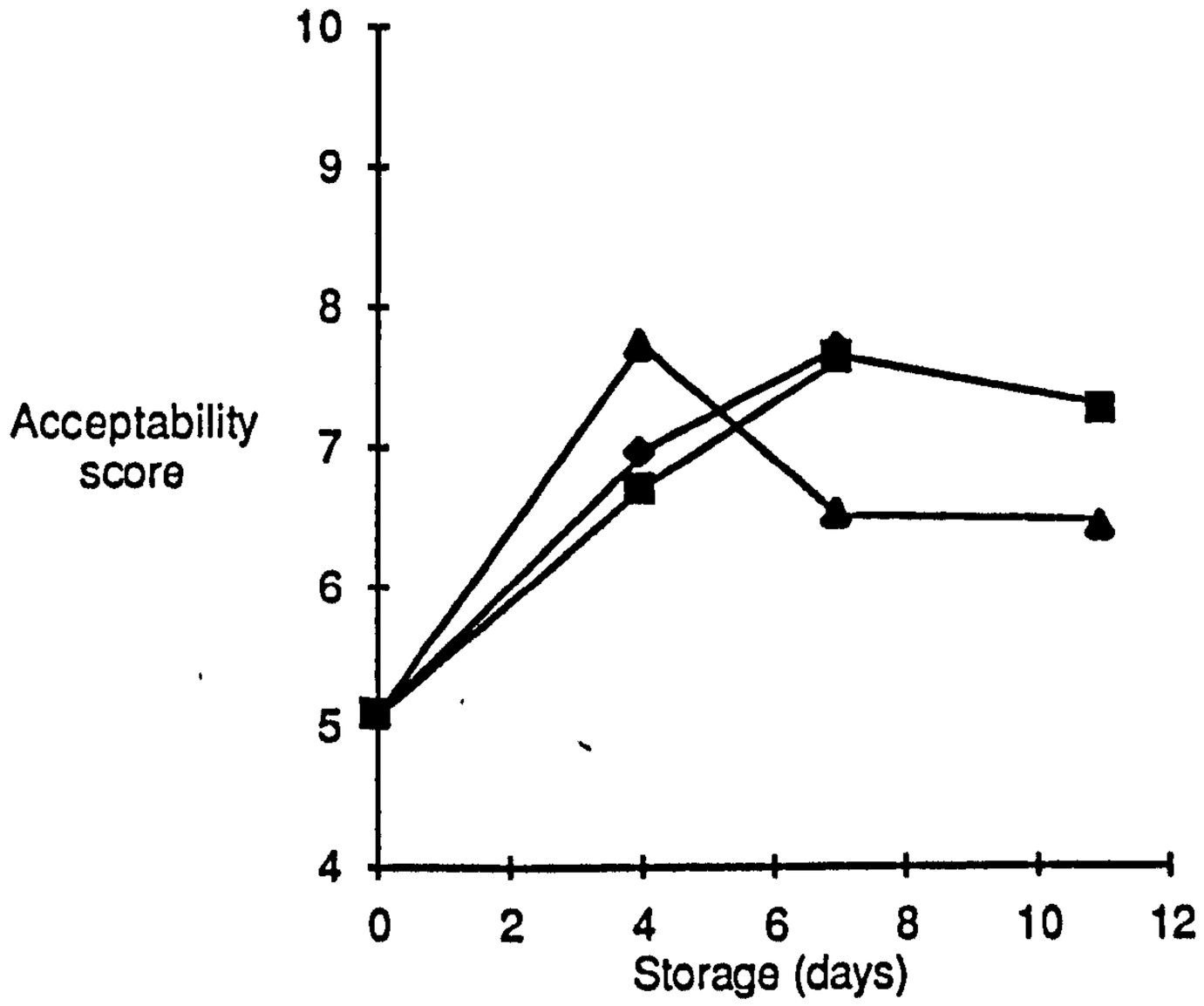
	Mean	S.E.	S.D.	Range	Kurtosis	Skewness
0 days	5.08	.421	3.67	14.8	-.45	.65
Vac 4	6.70	.404	3.48	14.1	-.64	.13
Vac 7	7.64	.434	3.60	13.9	-.48	-.15
Vac 11	7.26	.396	3.43	12.8	-.80	-.16
Map 4	7.73	.522	4.52	14.5	-1.42	-.02
Map 7	6.49	.532	4.42	15.0	-1.02	.35
Map 11	6.44	.391	3.37	14.0	-.73	.04
Cli 4	6.96	.455	3.88	15.0	-.65	.22
Cli 7	7.70	.495	4.11	15.0	-1.01	-.31

Samples scored by subjects altogether

	Mean	S.E.	S.D.	Range	Kurtosis	Skewness
0 days	4.67	.462	3.78	14.2	-.09	.851
Vac 4	7.28	.422	3.45	14.4	-.11	.181
Vac 7	8.73	.445	3.64	14.2	-.45	-.206
Vac 11	7.23	.466	3.84	15.0	-.51	-.070
Map 4	8.02	.545	4.46	14.6	-1.32	-.053
Map 7	7.25	.574	4.70	14.9	-1.25	.105
Map 11	5.81	.487	3.99	14.7	-.88	.437
Cli 4	7.54	.468	3.83	15.0	-.67	.049
Cli 7	9.09	.52	4.25	14.8	-.88	-.424

S.E.: Standard error S.D.: Standard deviation

Figure 8.3. The acceptability mean scores of chicken drumsticks scored by the subjects at Poole hospital. (n=69)



The mean score of the cling wrapped drumsticks stored for 4 days was lower (therefore more preferred) when scored by the hospital subjects than when scored by the Barclays subjects (the hospital subjects mean score was ranked 5th and 6th, whereas the Barclays subjects mean score for this sample was ranked 8th). However, the mean score of the cling wrapped chicken drumsticks stored for 7 days was one of the highest (least preferred) at both Barclays and the hospital.

The ranges in subjects scores at Poole hospital were slightly wider than those of the Barclays subjects. In addition the standard errors and the kurtosis values were greater, indicating a larger variation of scores around each mean. The products with the largest standard error were the MAP samples stored for 4 and 7 days and also the cling wrapped sample stored for 7 days, which were therefore the samples about which there was most disagreement between subjects (Table 8.6). The effect of storage life was greatest between 0 and 4 days of storage, after which time there was little change in acceptability score.

8.3.5. Multiple regression

Regression analysis fits a mathematical model to a set of data and allows the dependent variable or criterion to be predicted from the independent variables or predictors. In this study the criterion was the mean acceptability score of chicken drumsticks and the independent variables were either (i) the scores on the three discriminant functions, (ii)the scores on the 13 sensory characteristics of chicken drumsticks or the experimental variables (iii)packaging and storage life, or a combination of these. Thus a number of models were specified. The use of means for consumer acceptance as the dependent variable was recommended by Schutz (1983).

Regression assumes that each variable achieves at least interval level qualities. In the current study packaging was a nominal variable. This was overcome by means of dummy coding for each packaging category (therefore packaging consisted of 4 separate dichotomous variables). The correlation coefficients between the predictors and mean acceptability score are shown in Table 8.7. For all groups of scores the mean score for acceptability was correlated with discriminant function one and to lesser extent storage life. Correlations between packaging types and acceptability scores vary with location. For example, the cling wrapping has greater effect on acceptability of chicken drumsticks for Barclays subjects than the hospital subjects (Table 8.7).

Table 8.7. Pearsons correlation coefficients between the independent variables and the mean scores for acceptability.

	Acceptability mean score			
	Barclays		Poole hospital	
	1	2	3	4
	Scored in group of three	Scored in groups of nine	Scored in groups of three	Scored in groups of nine
Storage	0.48	0.36	0.42	0.24
Packaging:				
Vacuum	0.07	0.05	0.28	0.25
MAP	-0.27	-0.26	-0.002	-0.14
Cling	0.74	0.76	0.30	0.42
Discriminant functions:				
Function 1	-0.72	-0.71	-0.73	-0.68
Function 2	0.08	0.09	-0.02	-0.03
Function 3	0.09	0.06	-0.04	-0.02

Multiple regression was also used as a general technique for handling analysis of covariance (Nie et al., 1975). The objectives of the analysis of covariance were to determine whether the combination of packaging and storage life were able to contribute to the prediction of consumer acceptability and whether the effect of storage life on

acceptability was the same for each packaging group (test for interaction). In the absence of an interaction effect between packaging and storage life the analysis would allow packaging categories to be compared, while adjusting for the differences due to storage life and vice versa.

The appropriate sums of squares and F values were calculated from several regression solutions, which are shown in Appendix 12. A summary of the F values for the specified models is shown in Table 8.8.

Table 8.8. Analysis of covariance of acceptability score by packaging and storage life. (F values)

Source of Variation	Location: Barclays, Method of scoring: Groups of 3	Location: Barclays, Method of scoring: Groups of 9	Location: Poole hospital, Groups of 3	Location: Poole hospital, Groups of 9
1. Saturated model: all effects.	27.44b	49.50b	4.00	3.00
2. Additive model: Packaging, storage life & interaction.	39.00b	46.3b	3.13	3.50
a. Effect due to storage, adjusted for packaging.	9.83	1.60	0.13	1.00
b. Effect due to packaging, adjusted for storage.	39.44b	53.07b	3.10	4.26
3. Interaction between packaging and storage.	2.89	4.27	0.05	1.33

Level of significance:
a: P<0.001
b: P<0.01
c: P<0.025
d: P<0.05

In the saturated model, where all possible effects were accounted for only the Barclays subjects mean scores achieved significance ($P<0.001$) (Table 8.8). The effect of interaction between packaging and storage life were insignificant and so the main effects for Barclays subject scores were then examined. Packaging significantly ($P<0.01$) affected the acceptability of chicken drumsticks whereas storage life did not. Given the significant effect of storage life on the sensory characteristics of chicken drumsticks (Chapter 7) there were two possible explanations for lack of significant effect of storage life on acceptability. First, the day 0 samples constituted a packaging category which would have emphasized packaging differences as in the sensory profile the largest differences between drumsticks were those between day 0 and stored samples no matter how packaged. Second, the samples were presented to subjects in groups of three of like storage life but dissimilar packaging. Thus the differences between packaging types may have been more obvious to subjects than the storage life differences, due to presentation effects. Cremer et al. (1985) found that the general acceptability of vacuum packed chicken in sauce with noodles was significantly ($P<0.05$) reduced after 4 weeks chilled storage. Evaluations were made by a 13 member trained panel and therefore did not represent "consumer" acceptability.

The lack of significance in the hospital subjects analysis of covariance and hence regression equations was attributed to either the absence of differences in acceptability of chicken drumsticks due to packaging or storage life or the masking of underlying relationships by the use of mean scores (sub groups may have existed within the general population who held opposite opinions of acceptability, none of whom were represented by the mean score). Consequently individual differences were considered in the Prefmap analyses which is discussed in Section 8. Problems may have arisen due to scoring more than one sample on a single line scale, which would have discouraged the scoring of tied values (samples scored at the same point on

the scale) and would have forced subjects to differentiate between samples even if they could perceive no differences.

The presence of significant differences ($P<0.01$) between the samples scored by subjects at Barclays indicated that it may have been possible to develop some form of prediction equation. For the hospital subjects, where significant differences had not been demonstrated, any prediction equation would, at best, only be explaining the errors of the data rather than any true underlying relationships. This was confirmed by the "overall" test for goodness of fit of the regression equation to the hospital subjects data, which was insignificant.

The results from each regression model are summarized in Table 8.9.

Table 8.9. A summary of the results of the multiple regression analyses where mean score for acceptability was the dependent variable.

	Location			
	Barclays International		Poole hospital	
Scoring method	Groups of 3	Groups of 9	Groups of 3	Groups of 9
Independent variables				
Storage life & packaging				
r^2	0.94d	0.93d	0.69	0.70
S.E.E.	0.44	0.59	0.60	1.05
Regression coefficients:				
Vacuum packing	1.48	2.57d	2.32	3.92
MAP	0.93	1.94	2.01	3.20
Cling wrapping	3.17a	4.62a	2.40	4.28d
Storage	0.12	0.05	-0.03	-0.11
Constant	4.93	4.49	5.08	4.67
Discriminant function mean scores				
r^2	0.74	0.63	0.59	0.44
S.E.E.	0.79	1.18	0.68	1.29
Regression coefficients:				
function 1	-0.80	-0.99	-0.60	-0.83
function 2	0.33	0.44	-0.34	-0.36
function 3	1.01	0.83	-0.07	-0.20
Constant	6.78	6.87	6.57	6.85
Discriminant function scores				
r^2	0.53a	0.51a	0.53	0.46
S.E.E.	0.96	1.24	0.69	1.15
Regression coefficients:				
function 1	-0.57	-0.71	-0.42	-0.61
function 2	0.10	0.13	-0.01	-0.04
function 3	0.12	0.09	-0.04	-0.04
Constant	6.78	6.86	6.56	
Discriminant functions, storage life & packaging				
r^2	0.96	0.94	0.76	0.72
S.E.E.	0.74	1.06	1.17	2.05
Regression coefficients:				
storage	0.62	0.58	0.66	0.02
vacuum packing	10.99	11.15	19.17	4.22
MAP	9.53	9.53	16.39	4.31
cling wrapping	13.76	14.52	18.97	6.19
function 1	4.12	3.92	6.52	0.64
function 2	0.18	0.11	1.35	-0.82
function 3	0.26	-0.23	1.11	-0.21
Constant	-4.42	-4.35	-9.80	3.25

Table 8.9. (continued)

	Location			
	Barclays International		Poole hospital	
Scoring method	Groups of 3	Groups of 9	Groups of 3	Groups of 9
Independent variables				
Scores on the 13 sensory characteristics				
r^2	0.53a	0.51a	0.53	0.47
S.E.E.	0.96	1.25		
beta values*:				
Chicken flavour	-0.17	-0.23	-0.15	-0.22
Juiciness	-0.13	-0.16	-0.08	-0.14
Rancid odour	0.07	0.07	0.02	-0.02
Shrivelling	0.07	0.10	0.03	-0.05
First bite	0.06	0.07	0.02	-0.05
Constant	7.14		6.86	7.27

r^2: Correlation squared
S.E.E: Standard error of the estimate
Level of significance:
a: P<0.001
b: P<0.01
c: P<0.025
d: P<0.05

The overall goodness of fit of each regression model was measured by the correlation squared (r^2), which may be interpreted as the proportion of variance that is controlled or explained by the model.

Where the Barclays subject mean scores were combined with storage life and packaging, the percent of variation in acceptability score explained by packaging and storage life was between 93 and 94%, depending on the method of scoring. An additional 5 to 6% of the variation in acceptability score was explained by the interaction between packaging and storage life, ie the effect of storage life varied depending on the packaging type (Table 8.8.). In Table 8.10 the actual mean scores for acceptability (scored in three groups of three) are compared with the predicted scores. With the exception of the samples stored for 4 days, the rank order of the predicted and actual scores was the same.

Table 8.10 Predicted and actual mean scores for acceptability of chicken drumsticks scored by Barclays subjects (drumsticks scored in groups of three).

Sample	Storage life (days)	Actual score	Rank	Predicted score	Rank
Day 0 standards		4.93	1	4.93	1
Vacuum packed:					
	4	6.89	4	6.41	2
	7	7.25	6	7.50	6
	11	7.73	7	7.87	7
MAP:					
	4	6.34	2	6.71	4
	7	6.70	3	6.69	3
	11	7.18	5	6.71	5
Cling:					
	4	8.58	8	8.33	8
	7	8.94	9	9.15	9

For the Barclays subjects the variation explained was the same for both scoring methods, but the standard error of the estimate was less for scoring samples in groups of three. The standard error of the estimate indicates the absolute level of accuracy of any prediction, for example where pack and storage life were the independent variables and the Barclays subjects mean score (groups of three) was the criterion, the predicted acceptability mean score would deviate from the actual score on average by 0.44 score units. The standard error tended to be lower and the percent of variation explained was higher for the samples scored in groups of three than the samples scored in groups of nine (Table 8.9.). This indicates that the regression equations were better fitted to data obtained from samples scored in groups of three, rather than in groups of nine.

The size of the regression coefficients indicated the relative importance of each of the independent variables in the equation. For the Barclays subjects regression equation the order of importance of the regression coefficients was as

follows; cling wrapping, vacuum packing, MAP and lastly storage life (Table 8.9.), which would be expected given the size of their respective F values in the analysis if covariance (Table 8.8.).

Specifying the discriminant function mean scores as independent variables in the model rather than the experimental variables, decreased the percentage variation explained (Table 8.8.). Where the mean discriminant scores were the independent variable significance of the models were not attained, however, when the individual discriminant scores were used the percentage of variation explained by the discriminant scores was reduced, but the models were significant ($P<0.001$) (Table 8.9.). The majority of the variation in acceptability score was explained by discriminant function one.

Stepwise multiple regression was the method employed with the 13 sensory characteristics to determine the importance of each in influencing acceptability. Each of the sensory characteristics were included in the equation in order of their contribution to the variation in acceptability score explained. The first variable to be included was fried chicken flavour, followed by juiciness of flesh, which were therefore the two most important factors to influence consumer acceptability. In a consumer preference study on the effect of polyphosphate-salt injection on roast chicken breast muscle, Jones et al (1980) found that over one third of 226 consumers attributed the reasons for their first choice to its better flavour.

As the steps in the regression analysis proceeded, the F values for the regression coefficients of the independent variables not in the equation decreased, thus indicating that much of the variation in acceptability score accounted for by these variables was already accounted for by the variables in the equation. Only those variables with significant F values for their regression coefficients were retained in the regression equation (Table 8.8.).

8.3.6. Prefmap analyses

Carroll's (1972) Prefmap analysis is a method of multidimensional scaling (MDS) that may be used to relate preference data to independently derived measurements on the stimuli (the chicken drumstick mean discriminant scores plotted on discriminant functions 1 to 3). Prefmap fits four models, known as phases, of increasing complexity to each subjects scores, thus allowing individual differences to be examined. At the lowest level; phase 4, preference vectors are plotted in the stimulus space, which is the configuration of the mean discriminant scores. The direction of the preference vector indicates the direction of increased preference.

If the vector model or phase 4 cannot be fitted satisfactorily, the ideal point model or phase 3 maybe used . This model postulates that there is some optimum combination of the external measurements (discriminant scores), which represent the ideal point or most preferred chicken drumstick for a particular subject. Preference for any other sample is therefore directly related to its proximity to the ideal point, which contrasts with the vector model which assumes a single direction of increased preference throughout stimulus space. Phase three also allows for subject points to represent least preference on some or all of the dimensions.

The ideal point model may be extended to phase two, which permits individual subjects to weight the dimensions of the external space differently.

At the highest level; phase 1, each subject is allowed to rotate the reference axes of the external stimulus space and then to weight the new dimensions differently. Phase one was not applied in the current study as with only 9 data points the model would have been over specified and a prediction equation fitted which explained the errors in the

data as well as the true relationships. Phase two was applied to the data but the results were not considered useful because this model was also overspecified.

Prefmap may be either metric (interval data) or non-metric (ordinal data). Where metric models are employed an ANOVA may be constructed that enables the best fitting model for each subject to be selected and tested for significance for each individual. Initially a metric analyses was specified in order to test the significance of each model. Non-metric models were then examined as it was felt that the data had more ordinal rather than interval level properties.

As the maximum number of subjects included in a Prefmap programme was 49 a number of prefmap analyses were undertaken as shown in Table 8.11. Only those subjects for whom there was no missing data were included in the analysis.

Table 8.11. <u>The subjects included in each of the prefmap analyses.</u>

Analyses number:

1. Barclays subjects (numbers 1 to 43) samples scored in threes.

2. Barclays subjects (numbers 44 to 85) samples scored in threes.

3. Hospital subjects (numbers 1 to 33) samples scored in threes.

4. Hospital subjects (numbers 34 to 69) samples scored in threes.

5. Barclays subjects (numbers 1 to 36) samples scored in one group of nine.

6. Barclays subjects (numbers 37 to 72) samples scored in one group of nine.

7. Hospital subjects (numbers 1 to 33) samples scored in one group of nine.

8. Hospital subjects (numbers 34 to 36) samples scored in one group of nine.

From the metric analyses the number of subjects fitting the different models could be determined, the results of which are summarized in Table 8.12.

Table 8.12. The number of subjects fitting* each of the phases in the metric analyses.

*: Significance of F value for phase <0.05

Subjects	n	Phase 2	3	4	Fit by more than 1 model.	Not fit by any model.
Barclays:						
Scoring in 3's	85	4	5	9	5	72
Poole hospital:						
Scoring in 3's	69	5	6	10	6	58

In the metric analyses only 24 out of 154 subjects were fitted (significance of the F statistic <0.05) by one of the phases (samples scored in groups of three). In the non-metric analyses the fit of a subjects data to a phase of Prefmap was ascertained by the significance of their rank correlation coefficients with each phase, which are shown in Table 8.13. The number of subjects with significant correlations with each phase is shown in Table 8.14. As expected a greater number of subjects were fit by the non-metric analyses.

Table 8.13 The correlation coefficients between individual subjects acceptability scores and the non-metric phases of Prefmap

	Barclays subjects				Poole hospital subjects			
	Samples scored in groups of three		Samples scored on one line scale		Samples scored in groups of three		Samples scored on one line scale	
Subject number	Phase three	Phase four	Phase three	Phase four	Phase three	Phase four	Phase three	Phase four
1	.8456	.9855*	.8487	.9876	.9957*-	.9917*#	.9585	.9586*
2	.8572	.8712	.8004	.7655	.9561	.8595	1.000	.9905*#
3	.9951*+	.9341*#	.9325	.9168	.9875	.9862*#	.8604	.7895
4	.8894	.8575	.8569	.7843	.9879	.8889	.8276	.8187
5	.9665	.9624*#	.9109	.9127*	.8973	.8062	.9381	.8535
6	.8338	.6426	.9645	.9095*	.9899	.8033	.7672	.6668
7	.8585	.3692	.9251	.8500	.9936*-	.9886*#	.8741	.7903
8	.9497	.8191	.9925*-	.9933*#	.9978*-	.9967*#	.8339	.8187
9	.9018	.9838*#	.9882	.9958*	.9819	.9884*#	.9503	.6720
10	.8340	.8236	.6743	.6712	.7364	.7114	.8790	.8692
11	.9930*+	.9855*	.9281	.9968*#	.8618	.8630	.9983*+	.9906*#
12	.8101	.7873	.6250	.6221	.8969	.8086	.9263	.8428
13	.9903*+	.9916*#	.9732	.9105*	.9464	.9111*	.9543	.9920*#
14	.9713	.9963*#	.9451	.7785	.9989*-	.9987*#	.7892	.6829
15	.9758	.9711*	.9798	.9834*#	.9138	.8724	.9675	.9419*#
16	.9802	.7544	.8890	.6393	.8619	.7063	.99874	.9902*#
17	.8902	.7459	.8986	.9101*#	.9643	.9030*#	.7935	.7424
18	.9844	.7885	.9820	.7150	.9517	.8629	.5990	.6215
19	.9937*-	.9867*#	.9528	.9900*	.7791	.7794	.8350	.8244
20	.9269	.6847	.8653	.3637	.9998*+	.9805*	.9967*+	.9931*#
21	.8825	.7977	.8547	.7759	.8876	.8062	.9956*-	.9936*
22	.9934*-	.9851*#	.8555	.7692	.6744	.6438	.8659	.5506
23	.8414	.7415	.6077	.4816	.8155	.7767	.8109	.7760
24	.8163	.7431	.6750	.9901*#	.9893	.9916*#	.9948*-	.9882*
25	.9827	.9853*#	.7042	.7204	.8750	.8531	.8752	.8852
26	.9798	.9882*#	.9954*+	.9849*	.9068	.8633	.7789	.8751
27	.6301	.6015	.9929*-	.9919*#	.7062	.6205	.7703	.7832
28	.9935*+	.9882*#	.8793	.8899	.9013	.8954	.9154	.5140
29	.8200	.7881	.9387	.8473	.9763	.7298	.7752	.5980
30	.9158	.9676*#	.9793	.6206	.9913*+	.9806*#	.8795	.6723
31	.9673	.8047	.7657	.7306	.9895	.9896*#	.9523	.9717*
32	.8103	.7353	.8104	.7353	.9926*-	.9766*#	.7966	.7787
33	.9611	.9470*#	.9556	.8566	.7867	.7690	.9949*+	.9902*#
34	.8281	.7734	.9342	.7912	.9146	.9106*	.8704	.9893*#
35	.8427	.7979	.8634	.8369	.9762	.9743*#	.9299	.8047
36	.9245	.7008	.9119	.7455	.7289	.6245	.9566	.6906
37	.9556	.7643	.9459	.9964*#	.9848	.9977*	.9982*-	.9883*#
38	.9567	.7482	.8032	.5854	.9971*-	.8490	.8220	.7394
39	.7017	.6996	.9617	.8828	.8602	.8222	.9166	.7100
40	.9973*+	.9861*	.9961*+	.9952*#	.8947	.8695	.9874	.9213*#
41	.9208	.8429	.9469	.8774	.9898	.6857	.8539	.6276
42	.8689	.7494	.9926*-	.8724	.7923	.7103	.8539	.6276
43	.9781	.9757*#	.9622	.5574	.7256	.6802	.8098	.8006
44	.8713	.9930*#	.8918	.7560	.9937*-	.9869*	.8741	.9893*#
45	.9587	.9523*#	.9138	.8724	.9809	.9845*#	.9223	.8014
46	.9930*-	.9928*#	.9855	.8747	.6932	.7219	.9248	.6803
47	.9992*-	.9936*#	.9639	.7969	.9953*	.9882*#	.7621	.9842*
48	.8716	.8539	.8708	.8798	.9915*-	.9886*#	.7322	.8329
49	.9745	.8067	.9283	.9845*#	.8494	.8040	.9579	.9428*
50	.8786	.5434	.7488	.7406	.9180	.8779	.9662	.8477
51	.9537	.8859	.9949*-	.9882*#	.9897	.9823*#	.9229	.6708

Subject number	Samples scored in groups of three		Samples scored on one line scale		Samples scored in groups of three		Samples scored on one line scale	
	Phase three	Phase four	Phase three	Phase four	Phase three	Phase four	Phase three	Phase four
52	.9970*+	.9918*	.9191	.8578	.5070	.4517	.8690	.8626
53	.9807	.9670*	.9274	.7842	.9940*-	.9882*#	.6983	.4690
54	.6719	.6706	.8403	.8537	.9904*-	.9870*#	.9215	.7927
55	.9771	.9658*#	.9329	.8366	.9928*-	.9973*#	.8602	.3692
56	.9766	.9771*#	.9157	.9069*	.9997*+	.9850*#	.8102	.8478
57	.9893	.8843	.9726	.8413	.9754	.9756*#	.8534	.7418
58	.9954*+	.9851*	.9979*+	.9897*#	.9809	.6775	.8272	.8225
59	.7844	.7604	.8164	.8111	.3602	.6710	.9904*+	.9872*#
60	.9948*+	.9973	.9782	.9707*	.8509	.7209	.9467	.8515
61	.6334	.6329	.8507	.6249	.9973*-	.9950*#	.8714	.8724
62	.9859	.9852*#	.9434	.6725	1.000	.9898*#	.9737	.9148*
63	.8764	.8746	.9510	.9601*#	.9478	.9357	.9386	.9271*#
64	.8576	.9865*	.9931*+	.9873*#	.9951*-	.9884*#	.9675	.9501*#
65	.9950*-	.9937*#	.7210	.6636	.8645	.8662	.9204	.7885
66	.8542	.7930	.9426	.7853	.8383	.8286	.7499	.5510
67	.8787	.5720	.6829	.9855*#	.9876	.9841*#	.8154	.8328
68	.9893	.9790*#	.6750	.5434	.9328	.9244*#		
69	.7739	.7673	.9887	.9501*#	.9891	.9963*#		
70	.9839	.9448*#	.9225	.8021				
71	.8755	.8745	.9589	.7493				
72	.9965*+	.9969*#	.9953*+	.9918*				
73	.8910	.6265						
74	.9948*-	.9920*#						
75	.9897	.9967*#						
76	.9951*-	.9935*#						
77	.9716	.7859						
78	.9800	.9552*#						
79	.9933*+	.9807*						
80	.8146	.8074						
81	.9495	.9499*						
82	.9460	.8608						
83	.9398	.6587						
84	.9768	.9623*#						
85	.9031	.7427						

* P<0.05

\# Phase of Prefmap selected for individual

+/- Sign of the ideal point model (phase 3)

Table 8.14. The number of subjects fitting* each of the phases in the non-metric analyses.

*: Significance of rank correlation coefficient for phase <0.05

Subjects	n	Phase 3	Phase 4	Fit by more than 1 model.
Barclays:				
Scoring in 3's	85	17	40	10
Scoring together	72	9	36	8
Poole hospital:				
Scoring in 3's	69	13	38	10
Scoring together	67	7	21	7

It may be seen from Table 8.13 that some subjects were often fitted by more than one model. In the metric analysis the significance of the F statistic calculated between models indicated whether the more complex model should be adopted. In the non-metric analyses where more than one phase was significant the less complex model was adopted.

The phase of prefmap fitted to an individuals data was often influenced by the method of scoring used. For example, subject 14 from Barclays was fitted by a phase 4 model when scoring in groups of three (correlation coefficient=0.99) but not fitted when the samples were scored all together (correlation coefficient=0.78). The opposite pattern occurred with other subjects, for example, subject 24 from Barclays, whose correlation coefficient for phase 4 was 0.99 for scores from one group of nine samples and 0.74 for scores for 3 groups of 3. These differences between subjects illustrate one of the ways in which an individuals acceptability scores may differ. Consequently the decision whether to use the models applied to data from scoring in groups of three or in groups of nine was taken at an individual level.

From the results of the non-metric analyses, the best fitting phase for each individual was selected for further examination as shown in Table 8.13. The criteria for selection of a particular phase was based on the significance of the correlation coefficient and the complexity of the model (the least complex model with the highest significant correlation coefficient was selected).

8.3.6.1. Subjects fitted by the vector model (phase 4 of prefmap).

For each of the prefmap analyses the vectors corresponding to the preference direction for subjects fitting phase four were plotted in the stimulus space and are shown in Appendix 13. Each preference vector was drawn in between the point in the stimulus space whose coordinates were the standardized regression weights and the origin. The length of the line is arbitrary and so to illustrate any clustering of subjects a section of each preference vector was drawn on the circumference of a circle.

In order to examine all the subjects vectors simultaneously, the eight separate plots of subjects preference vectors on discriminant functions one and two were copied onto transparancies and overlaid over one another as shown in Figure 8.4.

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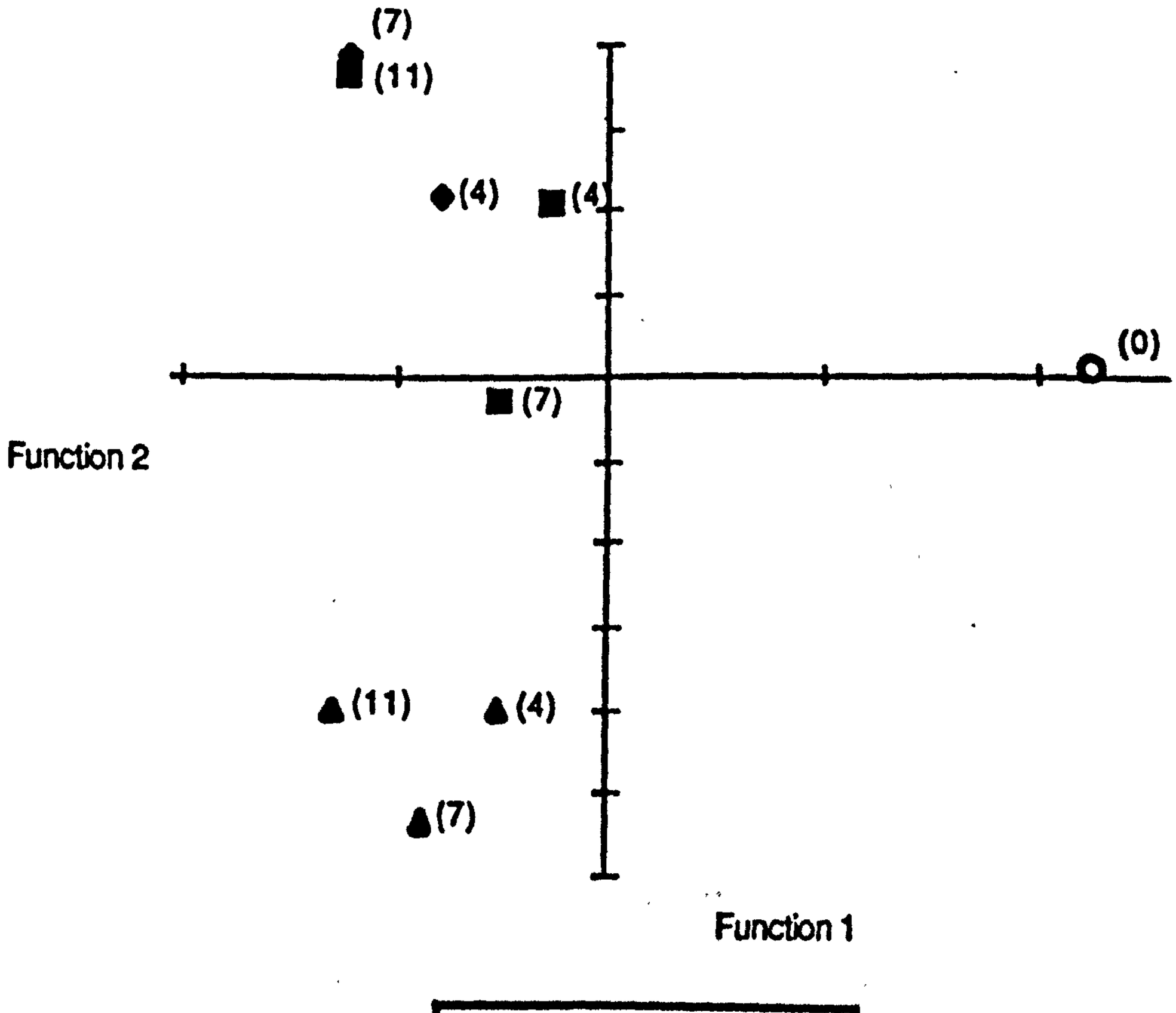
Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t



- Cling
- Vacuum
- MAP
- 0 days

Numbers in parentheses are storage life in days.

1. Barclays subjects (numbers 1 to 43),

samples scored in groups of 3.

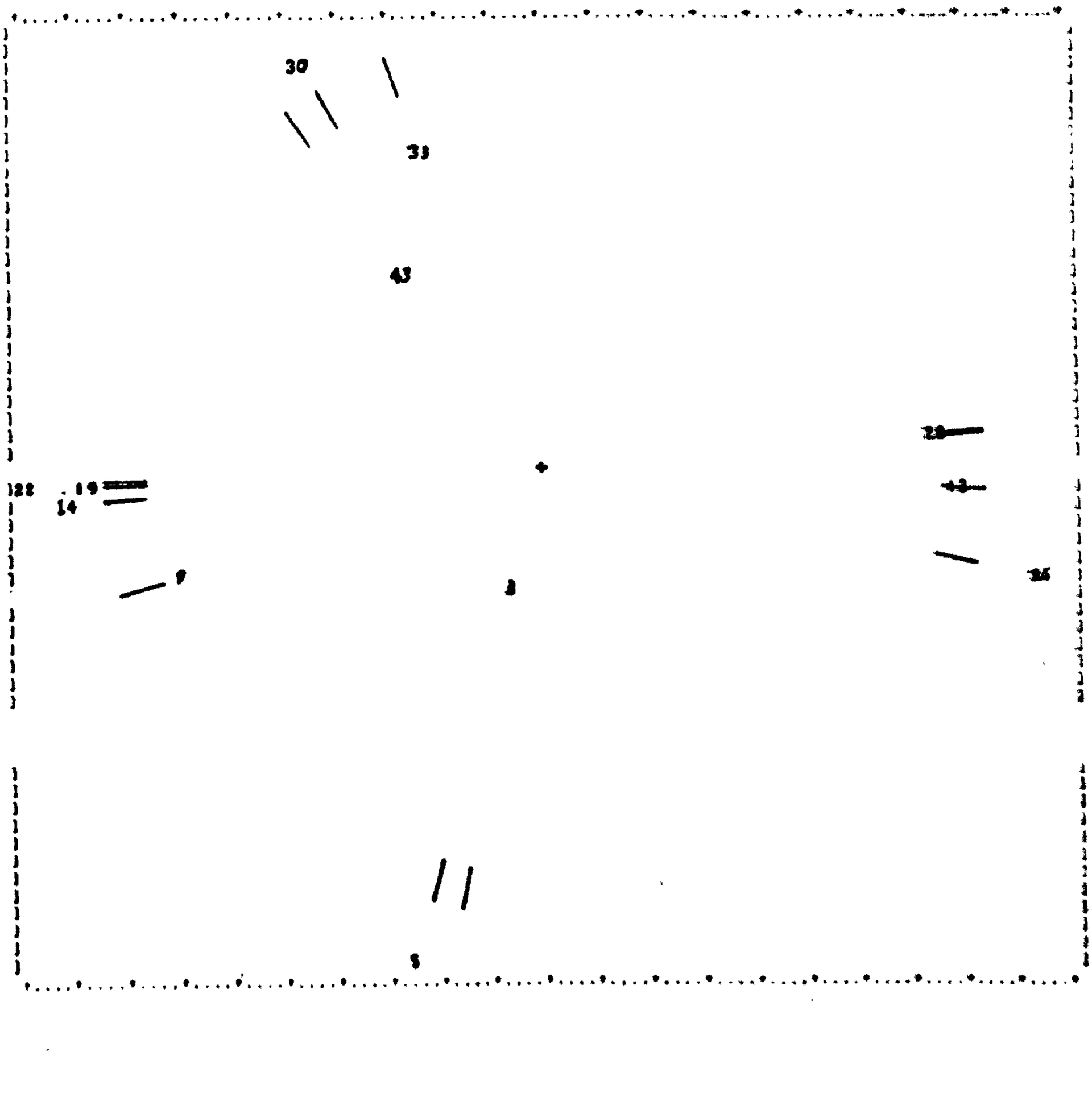
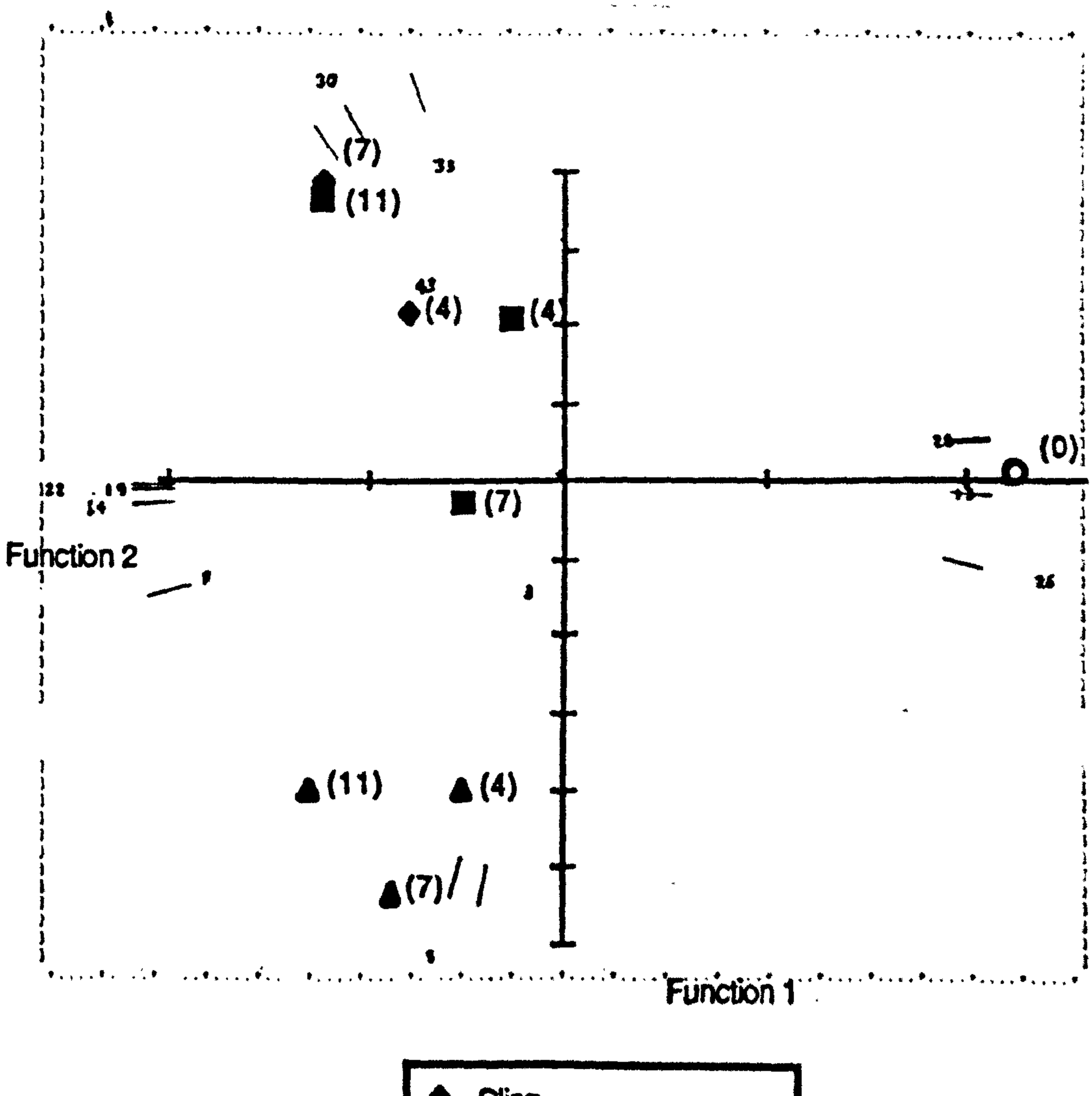
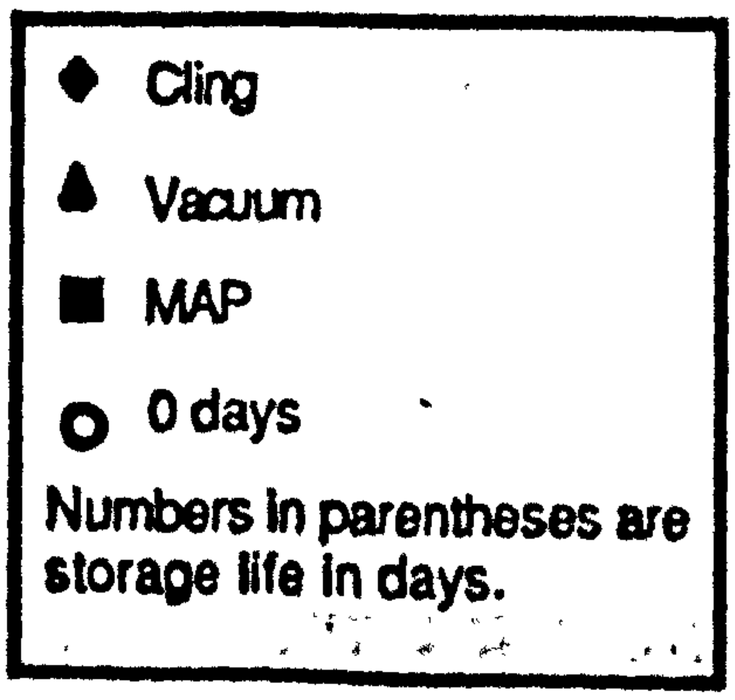


Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t





2. Barclays subjects (numbers 44 to 85),

samples scored in groups of 3.

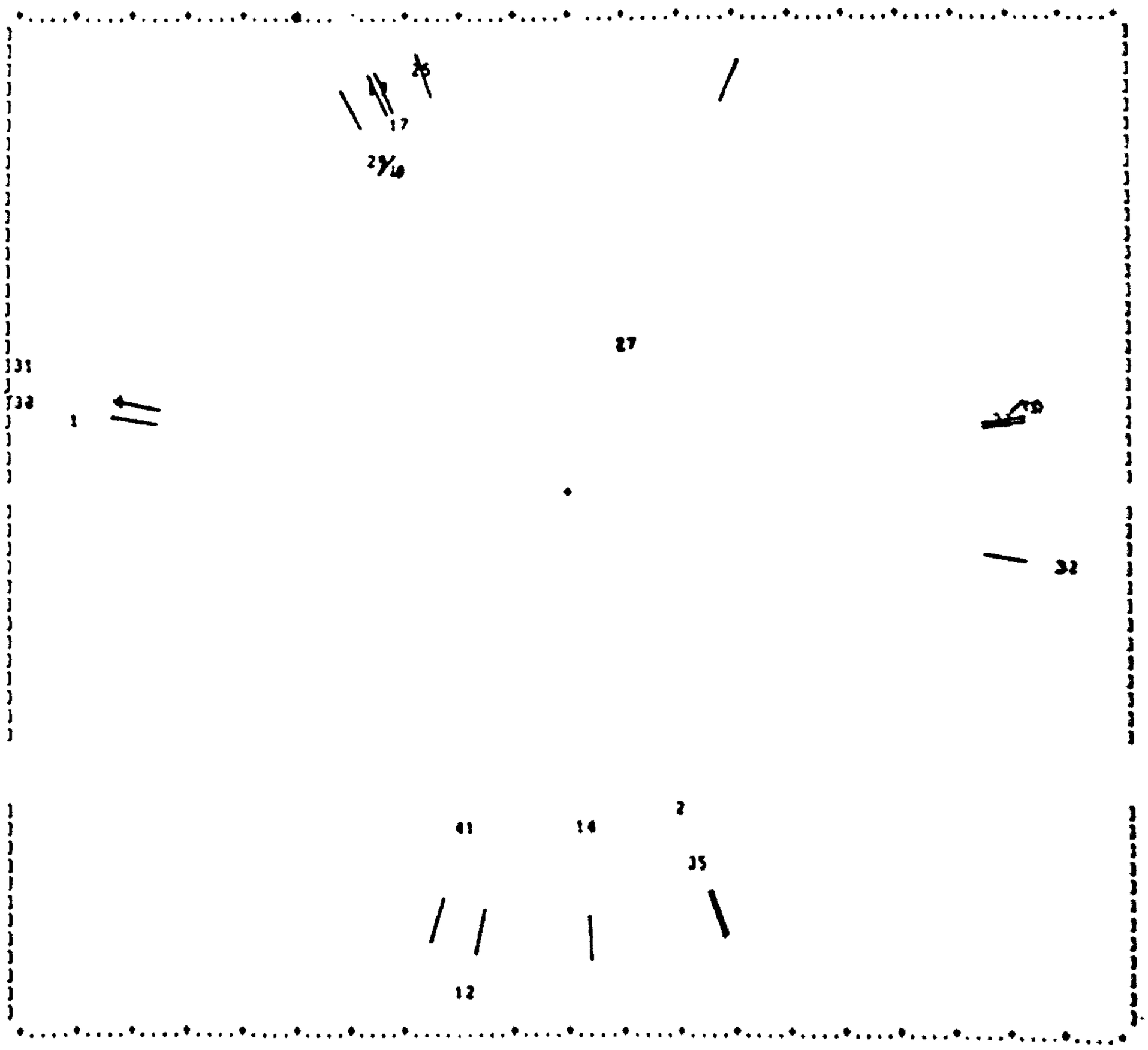
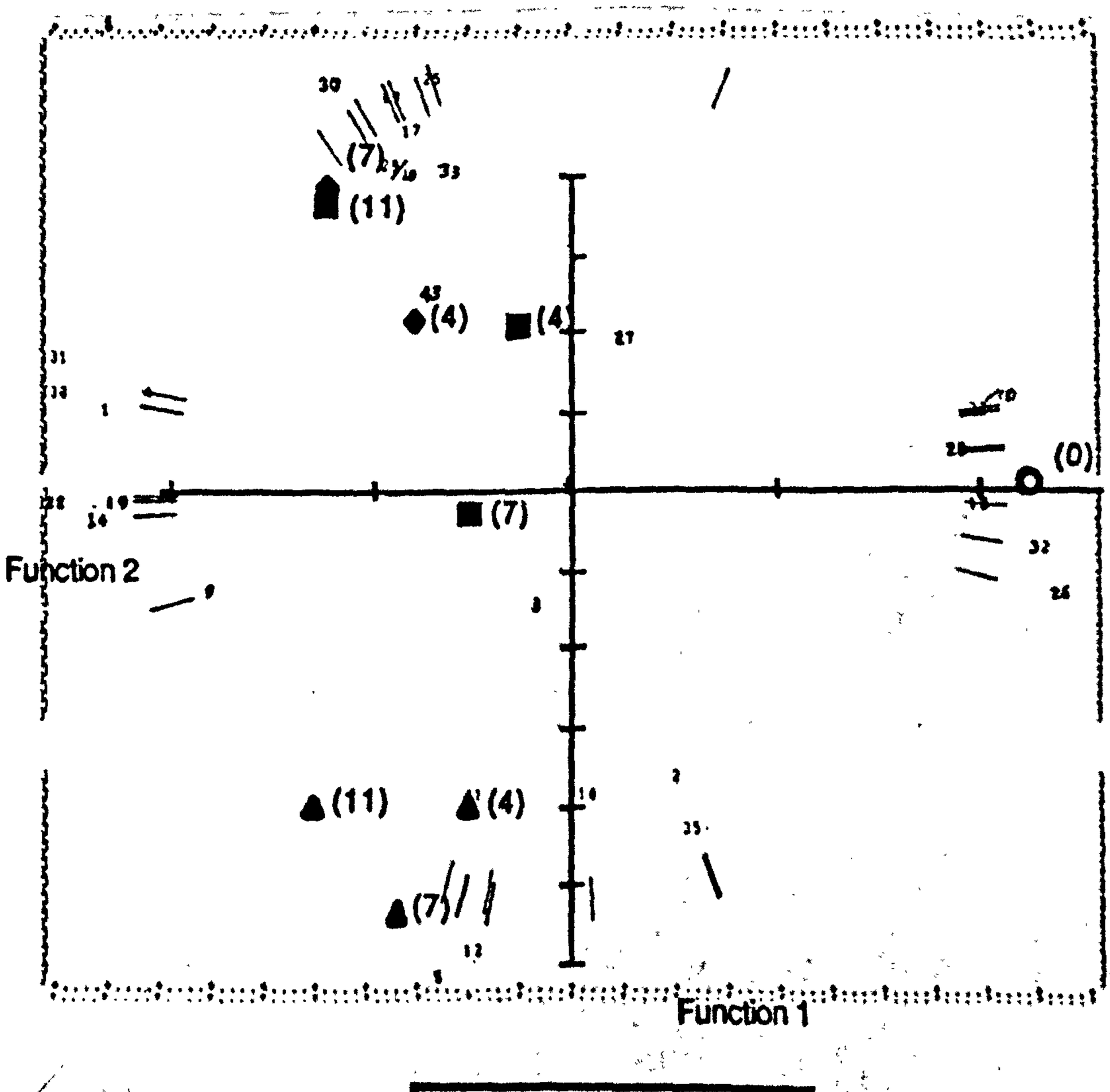


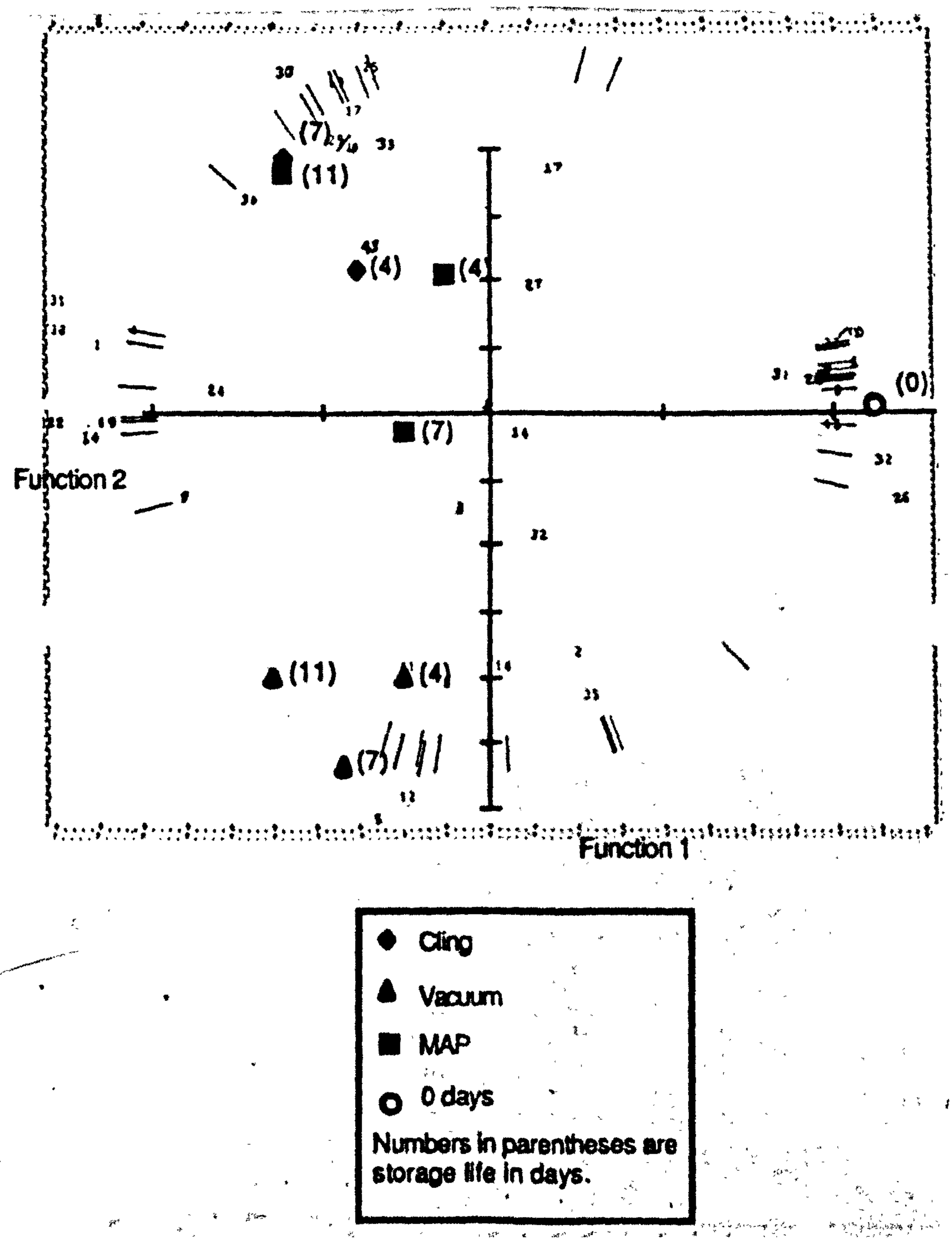
Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t



3. Hospital subjects (numbers 1 to 33)

samples scored in groups of 3.

Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t



- Cling
- Vacuum
- MAP
- 0 days

Numbers in parentheses are storage life in days.

4. Hospital subjects (numbers 34 to 69),
samples scored in groups of 3.

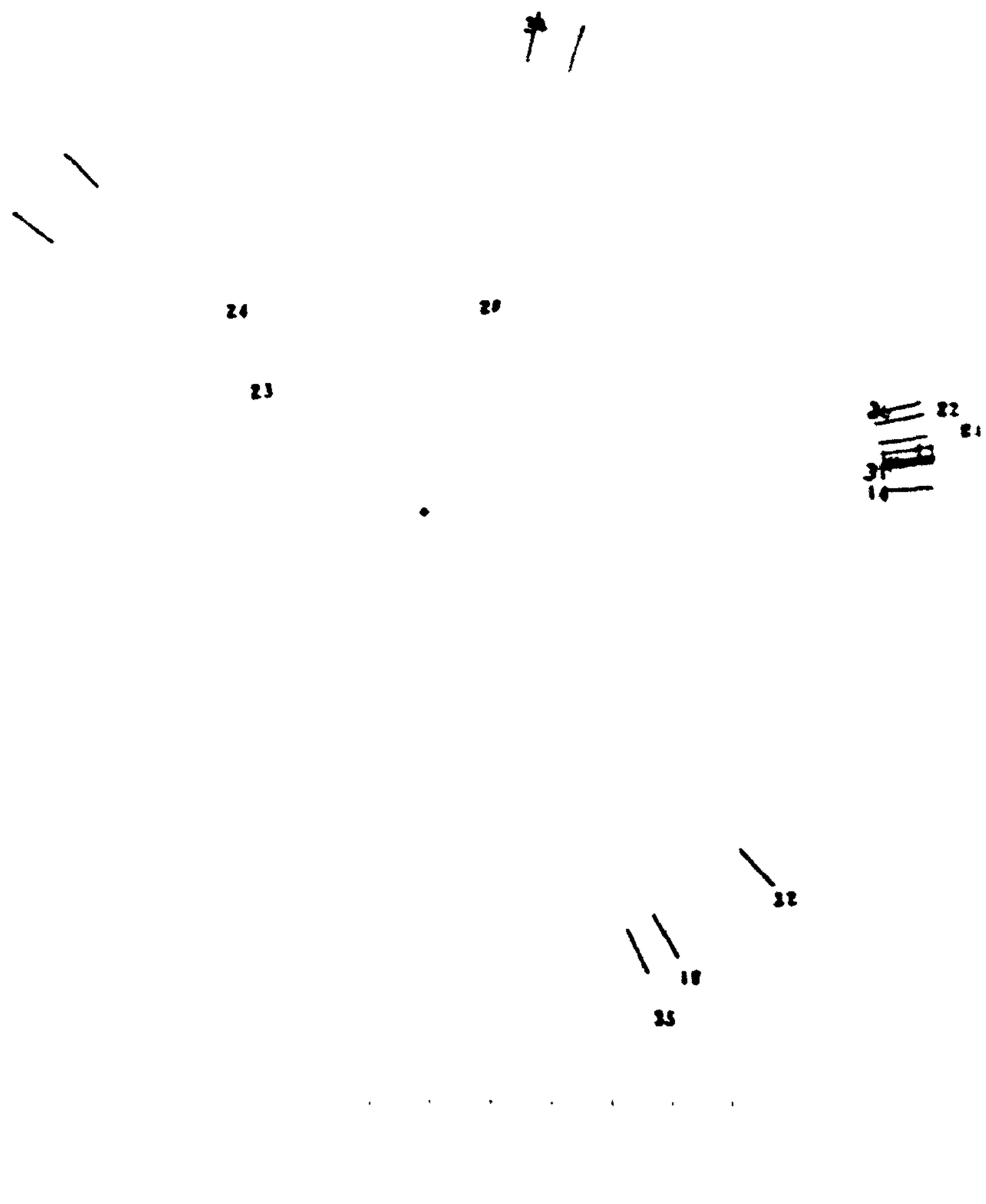
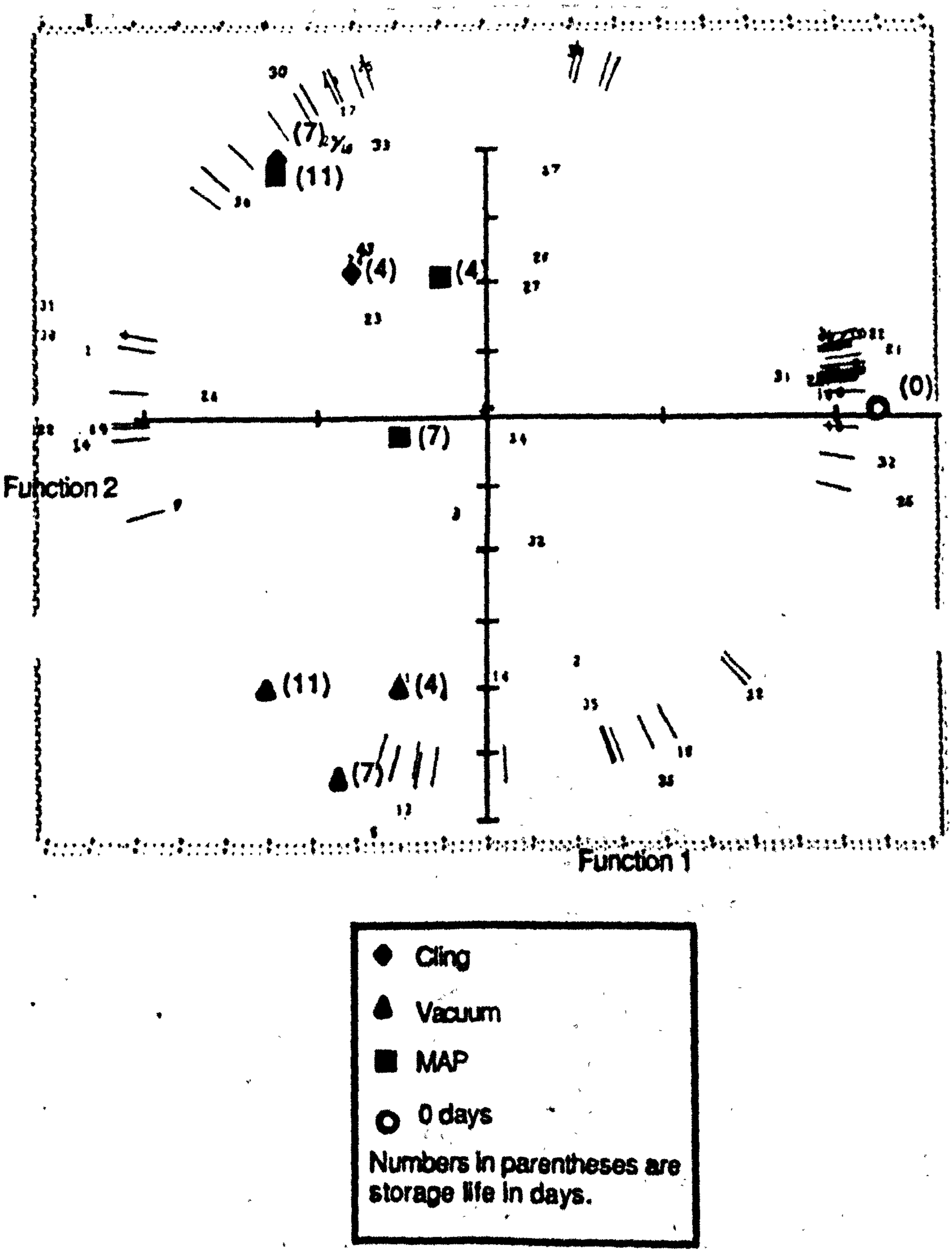


Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and tv



5. Barclays subjects (numbers 1 to 36),
samples scored in one group of 9.

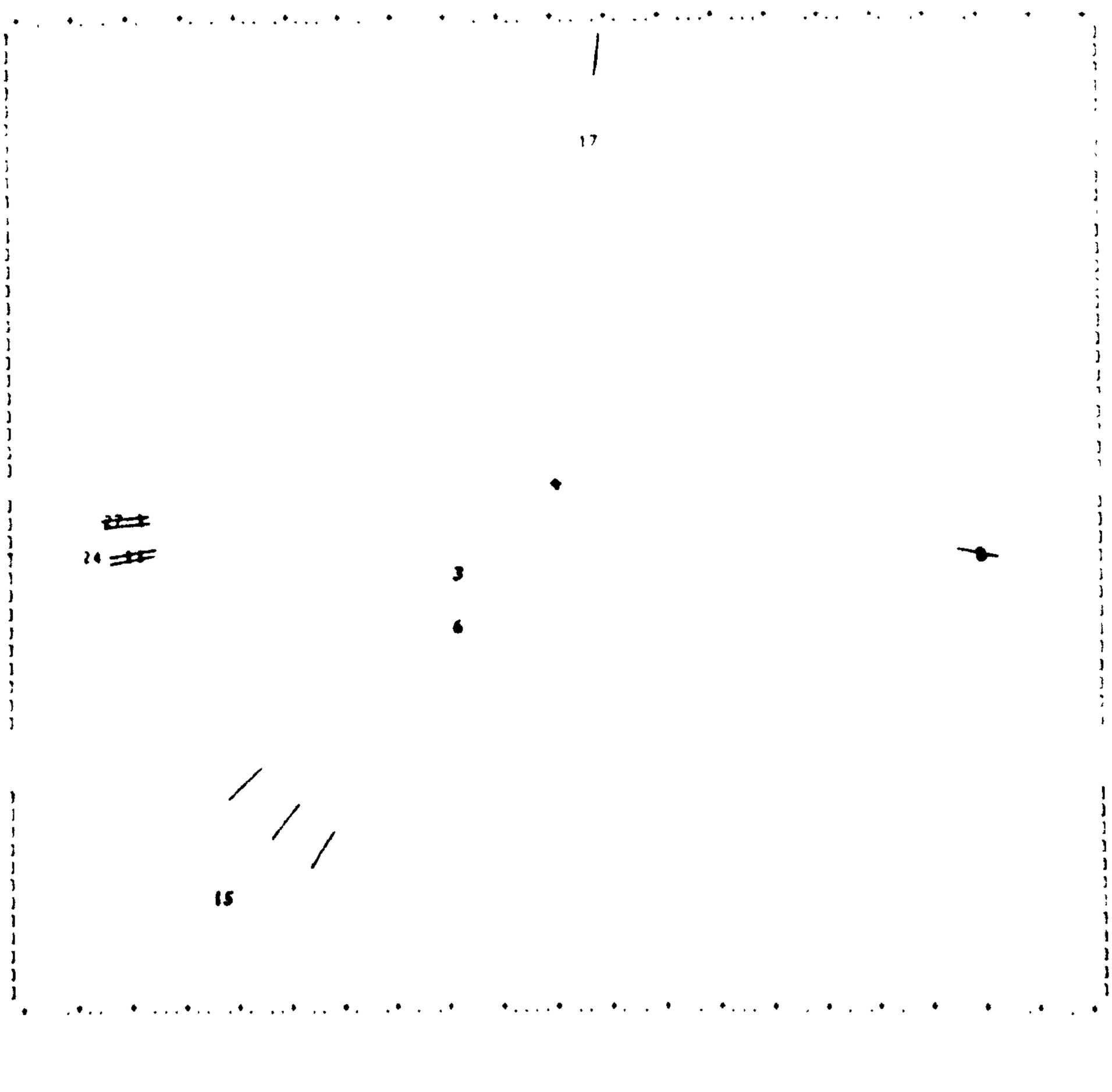
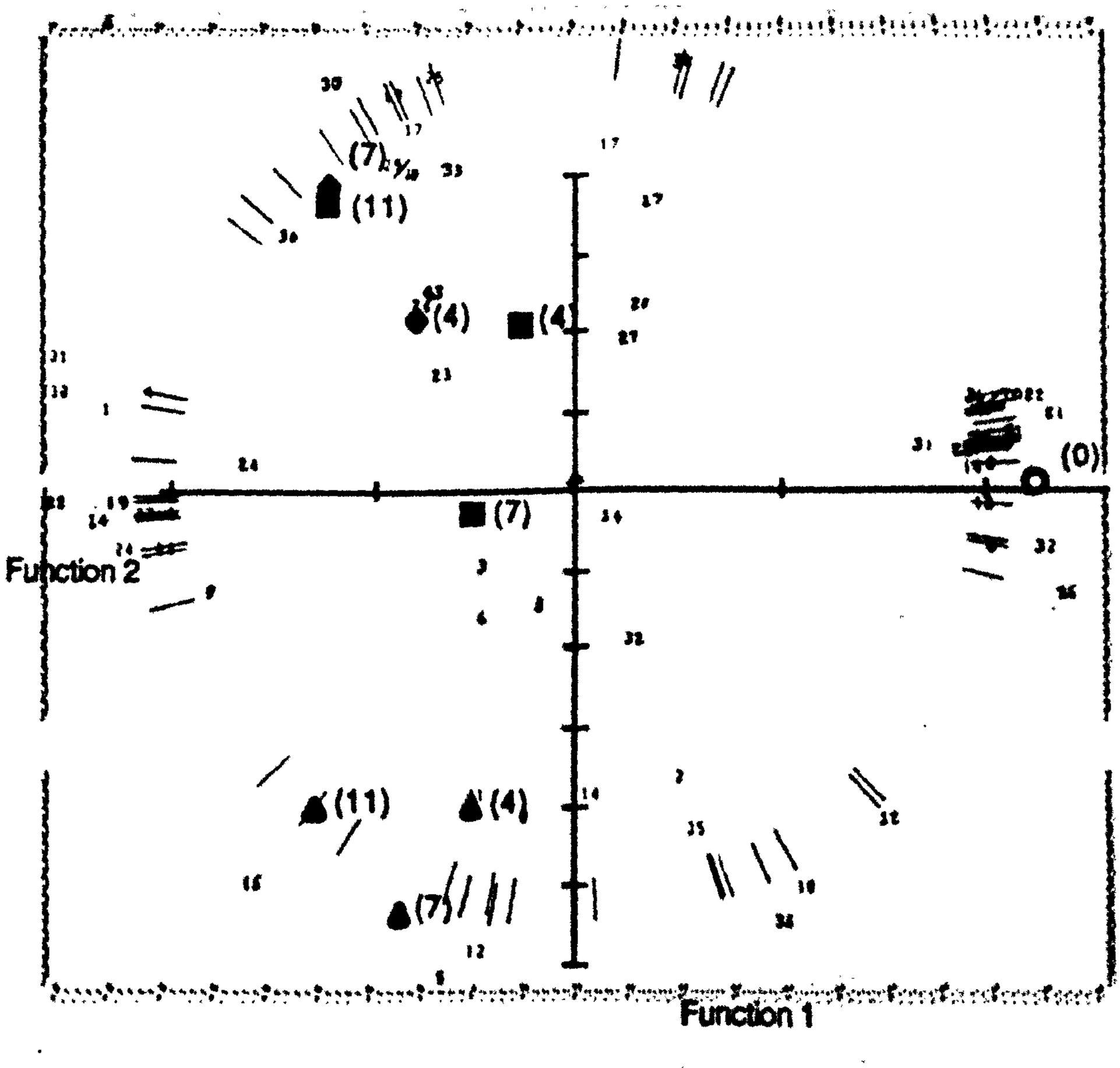


Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t



6. Barclays subjects (numbers 37 to 72),
samples scored in one group of 9.

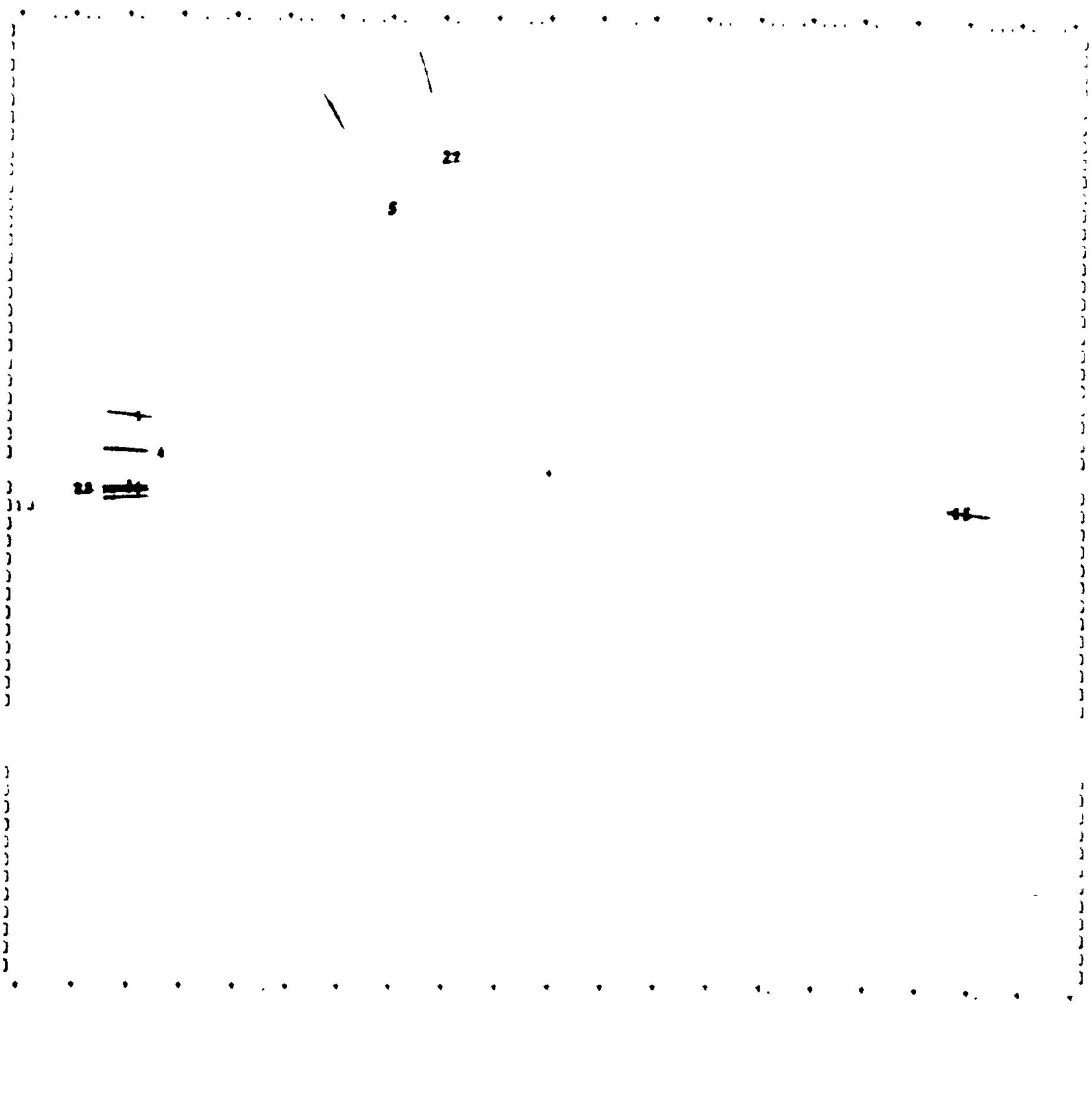
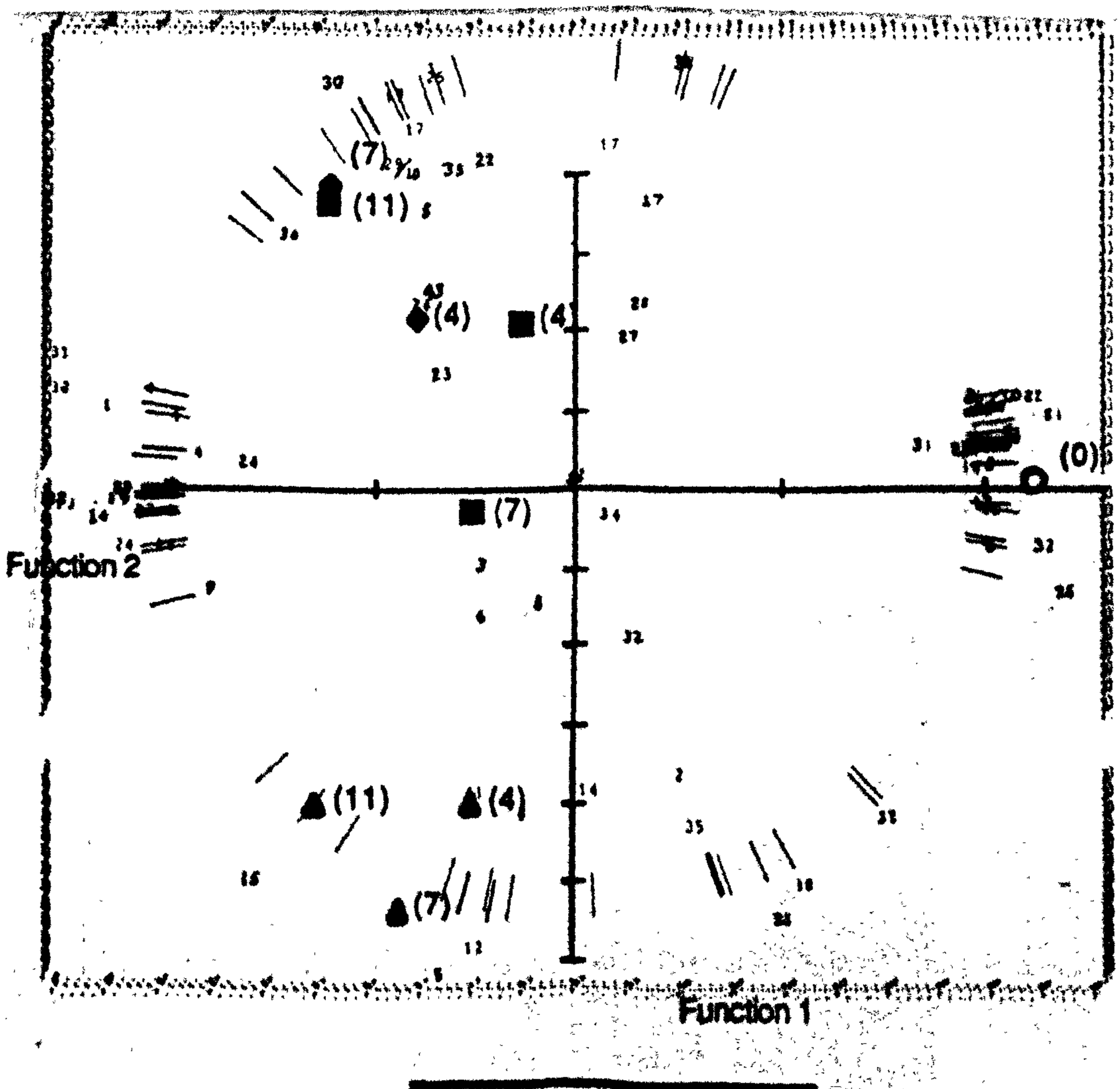


Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t



7. Hospital subjects (numbers 1 to 33), samples scored in one group of 9.

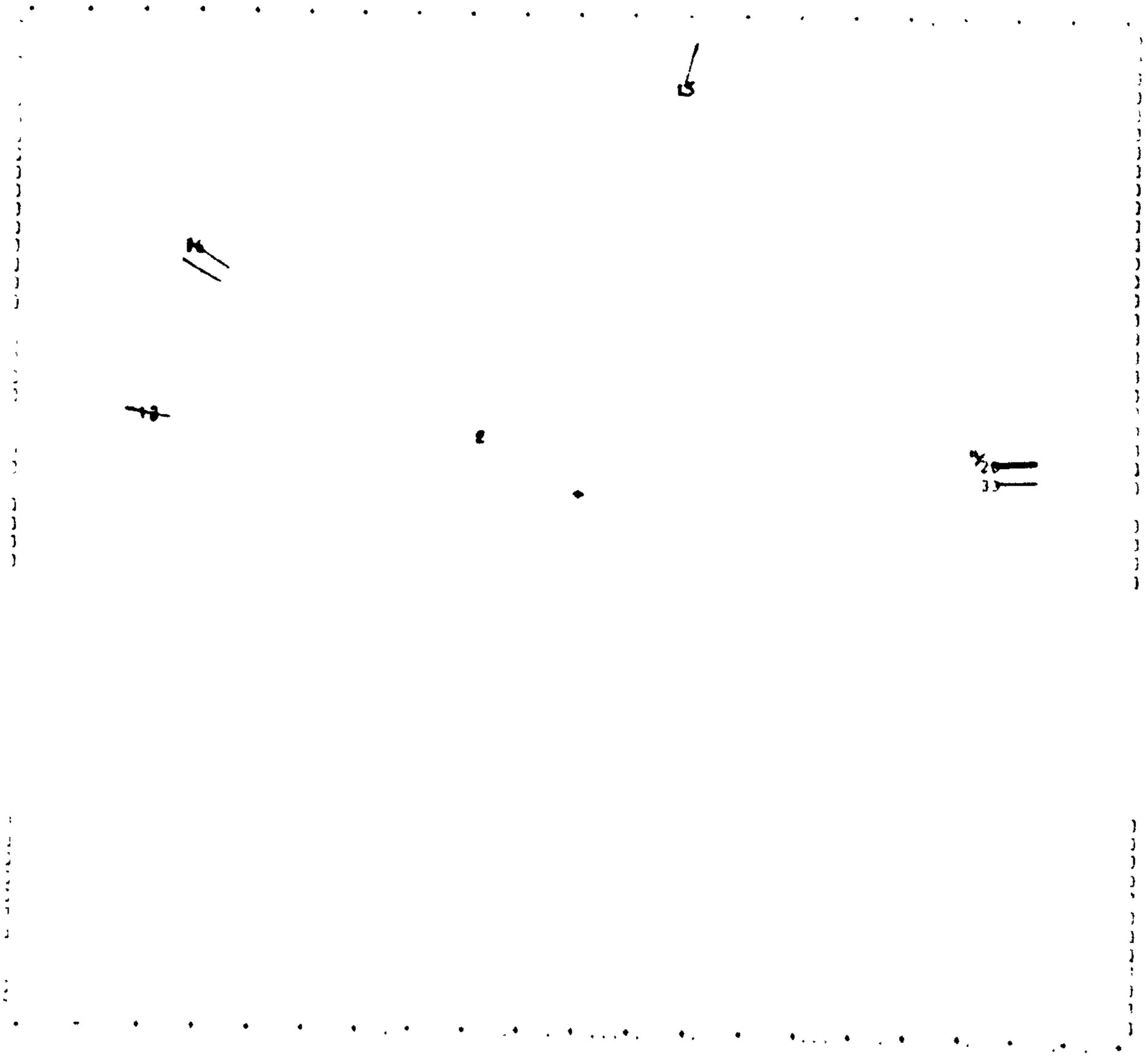
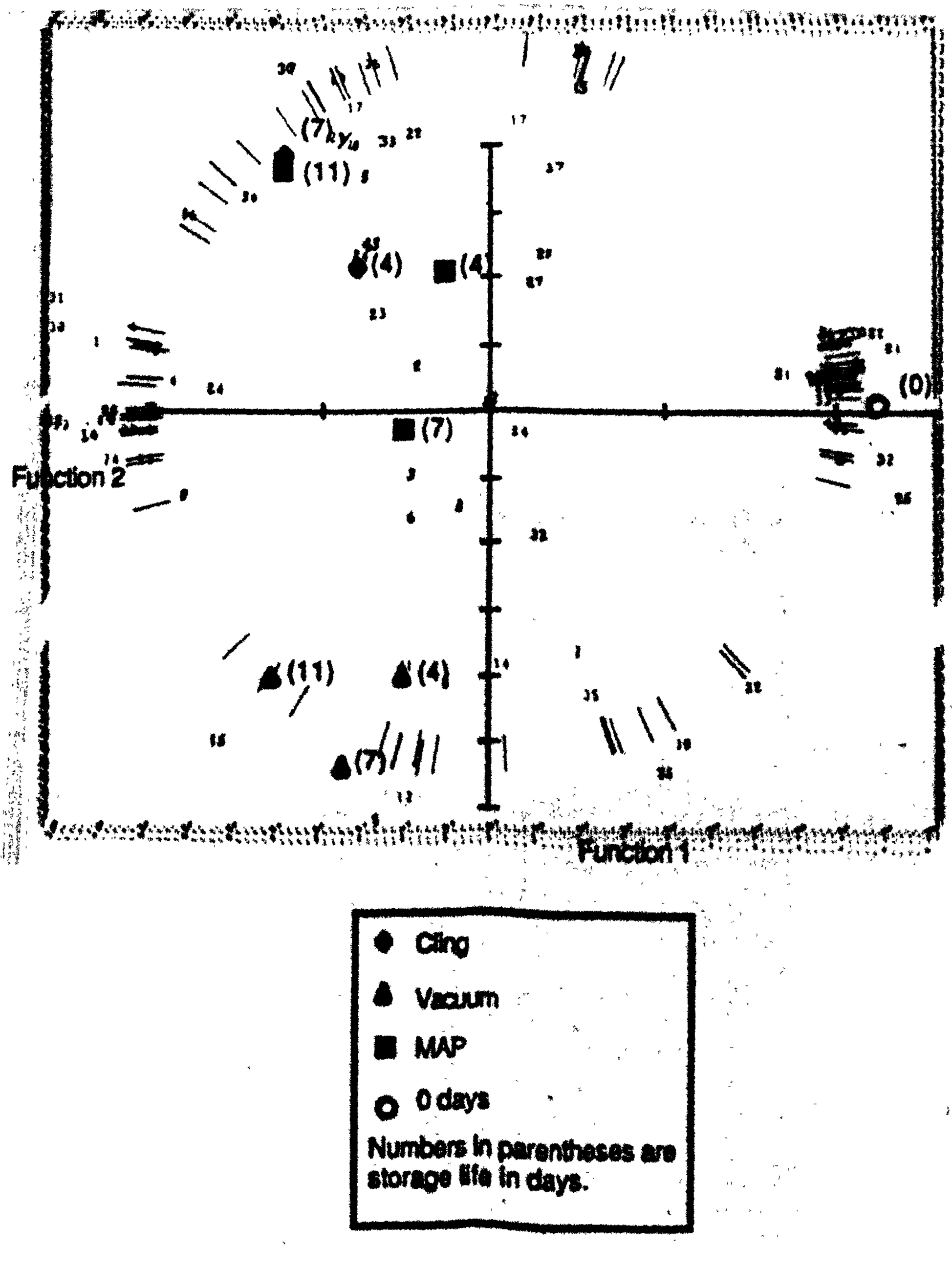
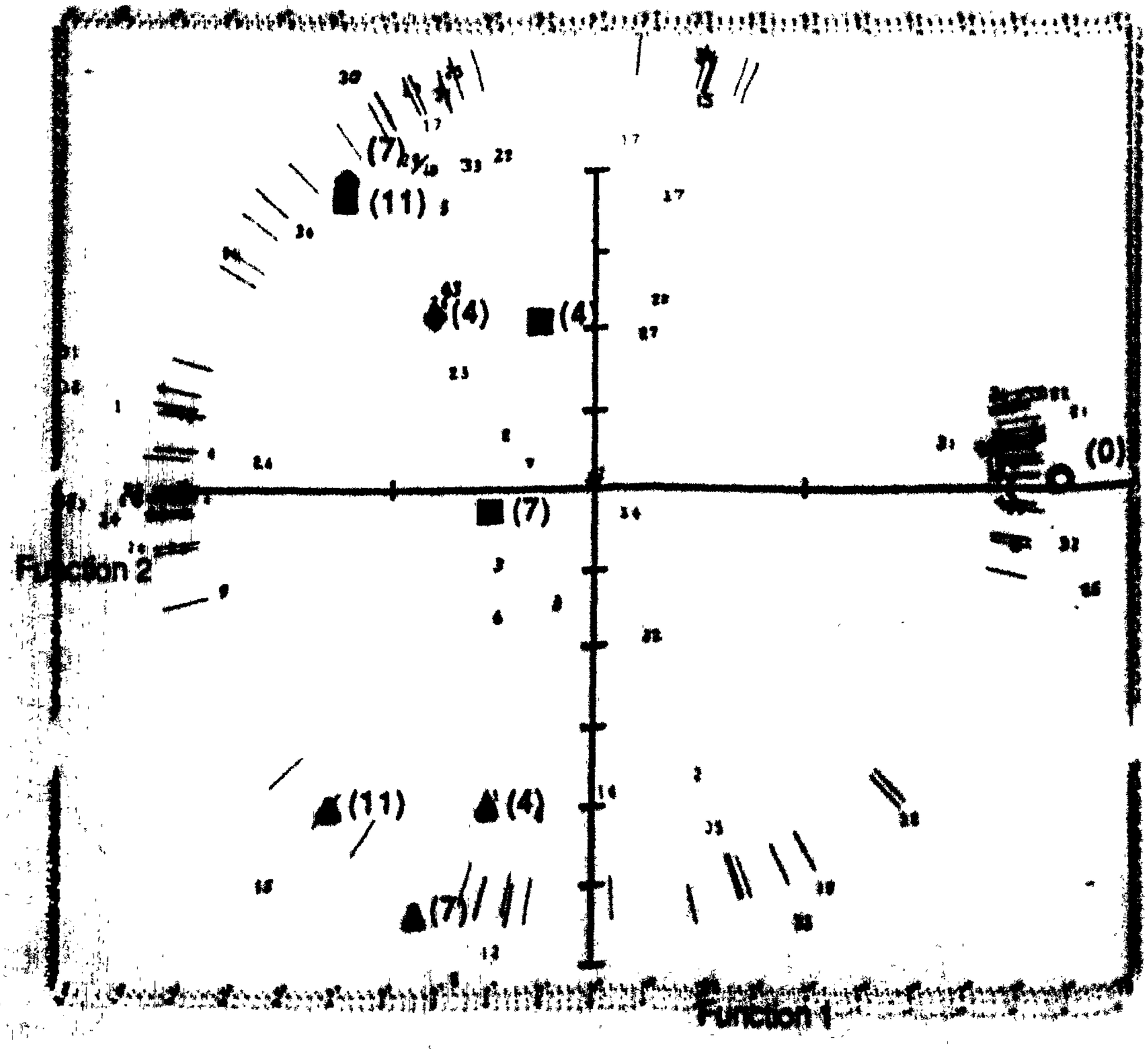


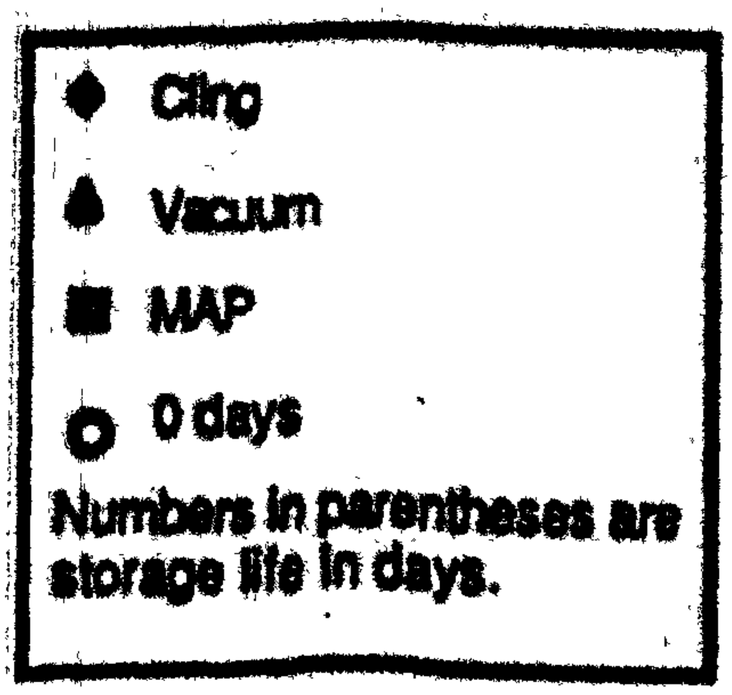
Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t



8. Hospital subjects (numbers 34 to 67),
samples scored in one group of 9.

Figure 8.4. The preference vectors (phase 4) of each non metri
prefmap analyses plotted on discriminant functions one and t





The concentration of vectors in Figure 8.4 was greater in the areas either side of discriminant function one, which indicates that for the majority of subjects fitting phase four, discriminant function one (representing storage life; Section 7.4.1., Chapter 7) was of greater salience to acceptability than discriminant function two (packaging).

High concentrations of subject vectors represented groupings or clusters of subjects with similar preferences. Two such areas were apparent in Figure 8.4; at either end of discriminant function one, thus constituting polar view points. This confirms the original suspicion that large differences in individual opinions had lead to unrepresentative mean scores and hence insignificant regression models for the hospital subjects (Section 8.3.4.). The proximity of these two groups of preference vectors to discriminant function one indicates that this dimension was of greater salience to their view of acceptability than the other dimensions. As dimension one was related to the storage life of the drumsticks, this disagrees with the results of the regression analyses, which indicated that storage life did not have a significant effect on consumer acceptability whereas packaging did (Section 8.3.5.).

On examination of the raw data it was apparent that certain subjects did indeed prefer the samples stored for longer periods. During the screening tests in the pilot sensory experiments, certain volunteers had also preferred the stored chicken meat (Section 6.3., Chapter 6). Similar results were reported by Glew et al., (1979) in their study on the effect of the presence or absence of O_2 on pre-cooked chilled chicken. They undertook preference tests with a taste panel of 18 subjects. On average the chicken stored for 4 days was preferred to the freshly cooked sample, which was attributed to the stronger flavour of the stored product. It was also noted that subjects were confused between fresh chicken flavour and the flavour of slightly oxidised chicken. In the present study misleading results due to confusion about the test proceedings were partly

discounted as each subject was personally instructed and shown a completed demonstration form prior to the test itself. In addition, the anchors on the acceptability scoring scale indicating which end represented greatest preference were repeated four times on each form.

The plots of vectors on the other dimensions (discriminant function one versus three, and function three versus two, as shown in Appendix 13) were examined to see whether the same grouping of subjects occurred. By eliminating any subject whose preference vector fell outside one of the two groups, group membership of the clusters was ascertained. The first group constituted 27.6% of the subject vectors and the second group 29.9%.

Subjects who were not members of these two clusters were members of smaller clusters or were scattered on the circumference of the circle in Figure 8.4. Such scattering of subject vectors represented individual differences in acceptability. This was not surprising when the variety of influences on subject responses was considered. Apart from differences introduced by the experiment due to lack of control of environmental or procedural variables and the inherent sample variability, there would be considerable influence of scoring patterns due to subject differences. For example, genetic and biological differences, differences in personality traits which influence interest, motivation and total performance, differences in intelligence and hence, their comprehension and interpretation of the task and lastly differences in language usage. For these reasons it was considered worthwhile to examine individual differences in scoring and try and relate them to subject characteristics to determine whether associations between scoring patterns and subject characteristics existed.

The characteristics of the two groups were then studied (Table 8.15) to determine whether group membership was characterized by any of the subject attributes examined in the background questionnaire.

Table 8.15 A summary of the characteristics of groups one and two from phase four of Prefman.

	Group 1 Number	%	Group 2 Number	%
Sex				
Male	4	18.2	9	50.0
Female	18	81.8	9	50.0
Age				
< 25	6	27.3	4	22.2
25 - <50	7	31.8	11	61.1
>50	9	40.9	3	16.7
Number of hours worked				
< 20	1	4.5	2	11.1
20 - < 35	2	9.1	3	16.7
>35	19	86.4	13	72.2
Use of staff restaurant				
Several times a week	20	90.9	15	83.3
Several times a month	2	9.1	2	11.1
Several times a year	-	-	1	5.6
Never	-	-	-	-
Frequency of eating chicken				
Several times a week	7	31.8	5	27.8
Several times a month	12	54.5	11	61.1
Several times a year	3	13.6	2	11.1
Never	-	-	-	-
Frequency of use of chilled food vending machines				
Several times a week	-	-	-	-
Several times a month	1	4.5	2	11.1
Several times a year	5	22.7	6	33.3
Never	16	72.7	10	55.6

There were no significant associations between any one attribute and group. However, the number of women tended to be higher in group one than in group two. In a study of consumer awareness and attitudes to food texture, Szczesniak and Kahn (1971) found that, in general, women were more texture conscious than men and were more experienced in recognizing and appreciating various textures. This was attributed to their greater involvement with food procurement, preparation and serving. Differences were also found in the textures men and women preferred.

8.3.6.2. Phase three or the ideal point model.

Of the scores of 53 subjects fitting the phase three model, only one (hospital subject 38, scoring in groups of three) was not also fitted by the simpler phase four model. When the ideal points of these subjects were plotted in the stimulus space, many of them lay outside the stimulus domain. This indicated that their phase three model was closer to the phase four than to the true ideal point model, as its position outside of the stimulus domain was essentially the same as the direction of preference. This confirmed the earlier observation that the data of most subjects was also significantly fitted by phase four. As the F ratio between phases three and four was not significant (calculated in the metric analyses), it was concluded that there was no significant advantage of adopting the phase three model.

The sign of each ideal point model (Table 8.13.), indicated whether the points represented the optimal acceptability point (positive sign) or the point of least preference (negative point). The existence of both positive and negative points agrees with the previous finding that individuals exist within the population whose prefmap solutions were polar opposites.

8.4. Conclusions

Twelve of the subjects participating in the acceptability trials were able to consistently score similar samples of chicken drumsticks. This was felt to substantially increase the reliability of the results.

On average the day 0 chicken drumsticks were preferred and the cling wrapped samples least preferred. The MAP drumsticks were preferred on average to the vacuum packed or cling wrapped drumsticks. This was attributed to the reduced

flavour changes occurring in the MAP drumsticks, as fried chicken flavour was the sensory attribute most associated with changes in acceptability (Chapter 7). Therefore MAP and vacuum packaging could be used by caterers to extend the shelf-life of cooked chicken, as even up to 11 days of vended storage these samples were significantly preferred to the cling wrapped samples stored for 4 and 7 days.

Although significant regression models were obtained they were found to be less representative of the consumer population than originally thought. The Prefmap analyses demonstrated the existence of sub groups within the population whose opinions on the acceptability of chicken drumsticks were polar opposites and that some subjects actually preferred the cling wrapped chicken drumsticks in which rancid flavours and odours had developed. Thus the prefmap analyses confirmed that a large proportion of the consumer population would not be catered for by the regression equation, which could represent a significant market segment.

In addition, the prefmap analyses demonstrated the nature of the subjects preference for chicken drumsticks, in that there was no ideal point of preference for most subjects, but instead preference was increased by pursuing a certain direction in the stimulus space.

CHAPTER 9

CONCLUSIONS

This study has taken a broad perspective of the effect of packaging and storage life on the quality of cooked menu items, incorporating microbiological, sensory and consumer studies, in an attempt to resolve some of the problems inherent in full meal vending, in particular the limited product shelf-life.

From a sensory point of view, MAP and vacuum packing maintain the quality of cooked menu items in a state ressembling the fresh product for considerably longer than cling wrap film. In the consumer study, on average, consumers least preferred the cling wrapped items and significantly preferred the MAP chicken drumsticks, even after 11 days of storage. This would indicate that MAP and vacuum packing are of potential benefit to the vending operator in extending shelf-lives. However, in the light of the microbiological studies, the situation is more complex, in that the effect of these packaging types on microbial growth is dependant on the nature and size of the initial microflora, which given the very nature of the industry (many small sites, variably trained food handlers, varying standards of equipment etc) cannot be predicted or assumed not to include pathogens. Thus a dangerous situation arises where the food items appear less perishable, while the possibility of toxicity, due to the growth of pathogenic bacteria is unaffected or even enhanced.

Before the use of MAP and vacuum packaging could be considered in the vending industry other methods of preventing the growth of pathogens present as a result of post processing contamination or insufficient heat treatment, would have to be adopted. Temperature control during storage was the simplest answer, as the prolific growth of the most common bacteria is prevented at temperatures below 10^{o}C. In the light of this, the results of the survey of operating temperatures of chilled food vending machines (CFVM) were

encouraging as only the upper halves of 2 out of 11 machines, gave readings above 10°C for more than 4% of the time. With the exception of the National Vendors Grand Gourmet (only one was surveyed) all the machines studied were able to maintain average temperatures below 5°C, although this temperature was not universally found. This was felt to be largely due to lack of management control.

Temperature control is critical to a hazard free system and so in order to persuade management to be more aware of and implement the temperature control required, they should be persuaded of the advantages of maintaining constant chill temperatures additional to reduced health risks, which include a longer microbiological shelf-life as demonstrated in the current study, and also optimum sensory quality. The concept of strictly controlling chill temperatures in order to reduce the health risk may be difficult to grasp for management who for years have left temperature control up to the equipment and have not had an outbreak of of food poisoning through their outlets. With the increase in interest in cook-chill systems, education is clearly required for all levels of food handling personnel, stressing the important role of caterers in the nations health and the upward trend of outbreaks of food poisoning caused by eating outside of the home.

With the advent of cook-chill and packaging techniques aimed at prolonging shelf-life, management control is even more fundamental to a hazard free system, as the opportunities for abuse are increased. Unlike the catering industry, the full meal vending industry nearly always seperates production from consumption by a period of cold storage and possibly distribution. Consequently, situations are more likely to occur which conflict with the DHSS (1980) cook-chill recommendations and therefore represent a potential health risk. This was confirmed by the survey of the full meal vending industry, where it was found that few organizations rapidly chilled freshly cooked food destined for CFVM's. The full meal vending industry is diverse and

includes individuals whose skills range from engineering to catering, thus knowledge of food hygiene and the DHSS recommendations varies enormously. It is not enough to hope that information and training programmes aimed at the caterer will filter through to the vending operator. The message of proper temperature control is surely important enough to make the full meal vending industry the direct target, either by means of their representative bodies such as the Automatic Vending Association of Britain or by training programmes initiated by the manufacturers and distributors of CFVM's. Such programmes would not only be a good marketing tool for the manufacturers, but would also reduce the risk of an outbreak of food poisoning, which would undoubtedly confirm the negative attitude of the majority of the population to vending in the UK.

Most of the advantages associated with MAP, such as a longer shelf-life, which facilitates distribution, would be gained by the vending operator and not by the consumer. For it is the consumer who would probably have to pay for the additional costs incorporated by these more expensive packaging techniques. Whether vending operators would be convinced that the extra costs outweigh the benefits gained, will depend on the size of their organization, their product range, their area of distribution and other factors influencing shelf-life requirements. With the smaller operators whose food preparation constitutes a small proportion of their total operation, the purchase of a blast chiller must be seen as their first priority.

The vending industry is already supplied by food manufacturers with confectionery, drink ingredients and long life snacks, such as crisps and nuts. The obvious next step for food manufacturers' to produce prepacked chilled cooked meal components for the vending industry would be a natural progression, especially as some of the retail foodstore chains have already introduced prepacked ready to eat chilled foods as part of their chilled product range. Chilled food vending could represent a new market for large food

manufacturers who, unlike the vending operator, are experienced at product development and have well developed distribution networks.

In addition to the contribution made by this study to improving the quality of stored cooked menu items, it has also made important methodoligical strides in the analyses of data from consumer studies. A supposition of both the sensory profiling experiment and the consumer trial was that people were as much a variable as the experimental variables introduced by the experimentor, hence the need for training of the judges used to construct the sensory profiles and the examination of individual differences in the consumer trial. The latter proved to be most worthwhile, in that significant regression models based on mean scores were developed, which according to regression methods, were reliable at predicting consumer preferences given th packagaging type and lengtn of storage life. However, the Prefmap analyses revealed that the mean scores masked underlying sub-groups within the population whose preferences for different samples were polar opposites. Neither sub group would have been catered for by the regression model and their existence would have been unnoticed if not for the Prefmap analyses.

REFERENCES

Abrahamsson, K.; De Silva, N.N. & N.Molin (1965) Can J Micro 11, 523-529

Adams, I.M.V. (1985) In: Food group symposium shelf-life of red meat, fish and poultry J Sci Food Agric 36: 122-128

Alford, J.A. & S.A.Palumbo (1969) Appl Micro 17, 528-532

Allen, J.R. & E.M.Foster (1960) Food Res 25, 19-25

Alm, F. & N.Molin (1961) Food Tech 15, 199-203

Amerine,M.A.; Pangborn, R.M. & E.B.Roessler (1965) Principles of sensory evaluation of food Academic Press

Angelotti, R.; Foter, M.J & K.H.Lewis (1961) Am J Public Health 51: 76-88

Anon (1982a) British Business 29 Jan 206-210

Anon (1982b) Chilled Foods 1 (1) 38-39,42

Anon (1984) Food Manuf 59 (3) 22, 23, 25, 65

Arafa, A.S. & T.C.Chen (1976) J FOOD SCI 41, 18

ASTM (1968)Manual on sensory testing methods, STP 434 American Society for Testing and Materials, Philadelphia, USA

AVAB (1983) Handbook and list of members of the Automatic Vending Association of Britain. Automatic Vending Association of Britain

Avens, J.S.; Poduska, P.J. & F.P.Schmidt (1978) J FOOD SCI 43, 453-456

Bailey, J.S.; Reagan, J.O; Carpenter, J.A. & G.A.Schuler (1979) J FOOD SCI 44: 134

Barnes, E.M. (1976) J SCI FOOD 27: 777-782

Barnes, E.M.; Despaul, J.E. & M.Ingram (1963) J App Bact 26, 415-427

Barnes, E.M. & C.S.Impey (1968) J App Bact 31, 91-107

Barnes, E.M.; Impey, C.S. & N.M.Griffiths (1979) Br Poultr Sci 20: 491-500

Barnes, E.M.; Impey, C.S. & R.T.Parry (1973) The sampling of chickens, turkeys, ducks and game birds. In 'Sampling - Microbiological Monitoring of Environment' Eds: Board, R.G. & D.W.Lovelock Academic Press

Basford, A.H. (1963) ROY SOC HEA 83, 103-110

Bayne, G.B.; Garibaldi, J.A. & H.Lineweaver (1965) POULTRY SCI 44, 1281-1284

Benjamin, M.J.W.; Wheather, D.M. & P.A.Shepherd (1956) J App Bact 19,159

Bennett, R.W. & W.T.Amos (1982) J FOOD PROT 45, (2) 157-161

Bergdoll, M.S. (1979) Staphyloccal intoxications. In: Foodborne infections and intoxications Eds; Riemann, H. & F.L.Bryan 2nd Ed

Beuchat, L.R. & R.V.Lechowich (1968) J App Bact 31, 414-419

Bjorkman,A. & K.A.Delphin (1966) Cornell HRAQ 7(3) 84

Blickstad, E.; Enfors, S.-O. & G.Molin (1981) J App Bact 50: 493-504

Blickstad, E. & G.Molin (1983) J FOOD PROT 46 (9) 756-763

Bobeng, B.J. & B.D.David (1978) J AM DIET A 73: 524-535

Bomar, M.T. (1981) Alimenta 20 (3) 59-65

Bonde, G.J. (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N.Skovgaard (1981) Academic Press 529pp.

Booth, D.A. (1981) In: Criteria of food acceptance Eds: Solms & Hall

Brecht, P.E. (1980) Food Tech 34(3)45

Broughall, J.M.; Anslow, P.A. & D.C.Kilsby (1985) J APPL BACT 55: 101-110

Bryan, F.L. (1978) J FOOD PROT 41: 816

Bryan, F.L.; Fanelli, M.J. & H.Riemann (1979) Salmonella infections. In:Foodborne infections and intoxications" Eds: Riemann, h. & F.L.Bryan 2nd Ed Academic Press

Bryan, F.L. & E.G.Kilpatrick (1971) Am J Public Health 61: 1869

Bryan, F.L. & J.B.Lyon (1984) J FOOD PROT 47 (12) 950-963

BSI (1980) Methods for sensory analysis of food: part 1, introduction and general guide to methodology. BS 5929

Bunch, W.L.; Matthews, M.E. & E.H.Marth (1976) J FOOD SCI 41: 1273-1276

Bunch, W.L.; Matthews, M.E. & E.H.Marth (1977) J FOOD SCI 42 (2) 565-566

Campbell-Platt, G. (1985) Institute of Food Science and Technology (UK) Proceedings 18 (1) 2-6

Carroll, J.D. (1972) In: Multi-dimensional scaling: Theory and applications in the behavioural sciences. Eds: Shepard, R.N.; Romney A.K. & J.B.Nerlave vol 1, Seminar Press, New York

CFPRA (1982) Notes on parametric and non parametric tests, central limits theorem and the t test as applied to profile scores. (unpublished)

Christiansen, L.N. & E.M.Foster (1965) Appl Micro 13: 1023-1025

Christopher, F.M.; Carpenter, Z.L.; Dill, C.W.; Smith, G.C. & C.Vanderzant (1980) J FOOD PROT 43: 259-264

Christopher,F.M.; Seideman, S.C.; Carpenter, Z.L.; Smith, G.C. & C.Vanderzant (1979) J FOOD PROT 42: 240-244

Cochran, WG & GM Cox (1957) Experimental Design. 2nd Ed. John Wiley & Sons, New York

Craven, S.E. (1980) Food Tech 5: 80-95

Cremer, M.L. & J.R.Chipley (1977) J FOOD SCI 42: 225-229

Cremer, M.L. & J.R.Chipley (1979) J FOOD SCI 44 (2) 317-321

Cremer, M.L. & J.R.Chipley (1980) J FOOD SCI 45: 1472-1477

Cremer, M.L.; Tong-Kyung Kwak Yum & G.J.Banwart (1985) J FOOD SCI 50: 891-896

Cunningham, F.E. (1982) J FOOD PROT 45 (12) 1149-1162

Dahl, C.A.; Matthews, M.E. & E.H.Marth (1978) J FOOD PROT 41: 788-793

Dahl, C.A.; Matthews, M.E. & E.H.Martn (1980) J FOOD PROT 43: 916

Dahl, C.A.; Matthews, M.E. & E.H.Marth (1981) J FOOD PROT 44: 128

Dainty, R.H. & J.R.Mabb (1971) Meat Research Institute Biennial Report, 1970-1971, London HMSO

Daniels, J.A.; Rajagopalan Krishnamurthi & Syed S.H.Rizvi (1985) J FOOD PROT 48 (6) 532-537

Davidson, C.M. & G.Webb (1973) Can Inst Food Sci Technol J 6: 41-44

Dawson, L.E. & R.Gartner (1983) Food Tech 7: 112-116

Department of Employment (1972) Classification of occupations and directory of occupational titles HMSO

DHSS (1980) Guidelines on precooked chilled foods. HMSO, London

Doyle, M.P.; Bains, N.J.; Schoeni, J.L. & E.M.Foster (1982) J FOOD PROT 45 (2) 152-156

Eddy, B.P. (1960) J App Bact 23 (2) 189-190

Egan, A.F. (1979) CSIRO Meat Research Report 6

Egan, A.F.; Ford, A.L. & B.J.Shay (1980) J FOOD SCI 45: 1745-1748

Eklund, M.W.; Wieler, D.I. & F.T.Poysky (1967) J Bacteriol 93:1461-1462

Elliott, RP (1963) J Bacteriol 85: 889-894

Enfors, S.-O & G.Molin (1978) J App Bact 45: 279

Enfors, S.-O & G.Molin (1981) Can J Microbiol 27: 15

Ennis, D.H.; Boelens, H.; Haring, H. & P.Bowman (1982) Food Tech 36,83-90

Enser, M. (1985) In: Food group symposium shelf-life of red meat, fish and poultry J Sci Food Agric 36: 122-128

Erichsen, I. & G.Molin (1981) J FOOD PROT 44: 866-869

Euromonitor (1984) The Catering Report 2nd Ed Euromonitors Publications Ltd.,

Eustace, (1981) J Food Tech 16: 73-80

Farrell, G.M. & M.E.Upton (1978) J Food Tech 13:15-23

Farrell, J. & A.H.Rose (1968) J General Microbiol 50: 429-439

Fennema, O.R. (Ed.) (1976) Principles of Food Science, Vol 4 part 1, Food Chemistry New York, Dekker

Francis, D.W.; Spaulding, P.L. & J.Lovett (1980) Appl Environ Microbiol 40: 174-176

Frijters, F.E.R. (1976) POULTRY SCI 55: 229-234

Fruin, J.T. & L.S.Guthertz (1982) J FOOD SCI 45 (8) 695-702

Gardner, G.A. (1966) J APPL BACT 29 (3) 455-460

Genigeorgis, C. (1973) In: Discussion of selected foodborne diseases Ed. C.Genigeorgis Acad Health Sci US Army Vet, San Antonio, Texas

Genigeorgis, C; Riemann, H & W.W.Sadler (1969) J FOOD SCI 34: 62-68

Genigeorgis, C. & H. Riemann (1979) Food processing and hygiene Ch.7 In: Foodborne infections and intoxications 2nd Ed Eds: Riemann, H. & F.L.Bryan

Georgala, D.L. & A.Hurst (1963) J APPL BACT 26 (3) 346-358

Gilbert, R.J. (1983) In: Food microbiology advances and prospects, Soc Appl Bact Symp series 11 Eds: Roberts, T.A. & F.A.Skinner Academic Press 47-63

Gilbert, R.J. (1985) Proceedings of CFPRA seminar on chilled foods, 7-9th May, Stratford-upon-Avon 173-180

Gilchrist, J.E.; Campbell, J.E.; Donnelly, C.B.; Peeler, J.T. & J.M.Delaney (1973) APPL MICROB 25: 244-252

Gill, C.O. & K.G.Newton (1977) J App Bact 43: 189-195

Gill, C.O. & K.H.Tan (1980) Appl Environ Microbiol 39: 300-319

Ginsburg, B. (1963) Cornell HRAQ 4 (1) 69

Glew, G.; Berg, R. & Yin Yam (1979) In: Advances in Catering Technology Ed: G.Glew Applied Science Publishers

Glew, G. (1985) Proceedings of CFPRA seminar on chilled foods, 7-9th May, Stratford-upon-Avon 83-90

Goepfert, J.M. & K.C.Chung (1970) APPL MICROBIOL 19: 190-192

Goepfert, J.M. & H.V.Kim (1975) J Milk & Food Tech 38: 449-452

Gray, J.I. (1978) J AM OIL CH 55: 539

Gray, R.J.H.; Hoover, D.G. & A.M.Muir (1983) J FOOD PROT 46 (7) 610-613

Griffiths, N.(1985) In: Food group symposium shelf-life of red meat, fish and poultry J Sci Food Agric 36: 122-128

Hall, H.E. & R.Angelotti (1965) APPL MICROB 13: 352-357

Hanna, M.O.; Stewart, J.C.; Zink, D.L.; Carpenter, Z.L. & C.Vanderzant(1977) J FOOD SCI 42 (5) 1180-1184

Harris, N.D. & R.C.Lindsay (1972) J FOOD SCI 37: 19-22

Henry, K.G.; Savell, J.W.; Smith, G.C.; Ehlers, J.G. & C.Vanderzant (1983) J FOOD SCI 48: 1735-1749

Hess, E.; Ruosch, W. & C.Breer (1980) Fleischwirtschaft 60: 1513

Hobbs, B.C. (1979) Ch 3 In: Foodborne infections and intoxications Eds; Riemann, H. & F.L.Bryan 2nd Ed

Hobbs, G. (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N.Skovgaard (1981) Academic Press 529pp.

Hobbs, G.; Cann, D.C. & B.B.Wilson (1969) J Food Tech 4: 185-191

Horsfield, S. & L.J.Taylor (1976) J Sci Fd Agric 27: 1044-1056

Huss, H.H. (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

ICC Business Ratios (1985) The automatic vending industry. 5th Ed. ICC Business Ratios

Industrial Society (1984) Survey of catering prices, costs and subsidies

Ingraham, J.L. & J.L.Stokes (1959) BACT REV 23: 97

Ingram, M. (1951) Proc Soc App Bact 14: 243-260

Ingram, M. (1962) J App Bact 25: 259-281

Ingram, M. & B.M.Mackey (1976) In: Innibition and inactivation of vegetative microbes. Eds: Skinner, F.A. & W.B.Hugo Academic Press

Jackson, H. (1974) J APPL BACT 37: 59-64

Jacobson, M. & H.H.Koehler (1970) J AGR FOOD 18: 1069-1072

Jakobssen, B. & N.Bengtsson (1972) J FOOD SCI 37: 230-233

Jantavat, P. & L.E.Dawson (1980) POULTRY SCI 59: 1053-1058

Jay, J.M. (1978) Modern Food Microbiology Van Nostrand Reinhold 2nd Ed

Jones, J.M.; Griffiths, N.M.; Grey, T.C.; Wilkinson, C.C.L. & D.Robinson (1980) Lebensmittel Wissenschaft und Technologie 13 (3) 145-147

Jones, J.M.; Mead, G.C.; Griffiths, N.M. & B.W.Adams (1982) POULTRY SCI 23: 25-40

Jones, A.H. & A.G.Lockhead (1939) Food Res 4: 203-216

Julseth, R.M. & R.H.Diebel (1969) APPL MICROB 17 (5) 767-768

Kapperud, G. & G.Langeland (1981) Current Microbiol 5: 119-122

Kempton, A.G. & S.R.Bobier (1973) CAN J MICRO 16: 287-297

Kereluk, K; Peterson, A.C. & M.F.Gunderson (1961) J FOOD SCI 26: 21-25

Kokoczka, P.J. & K.E.Stevenson (1976) J FOOD SCI 41: 1360-1362

Kossovitsas, C.; Navab, M.; Chang, C.M. & G.E.Livingston (1973) J FOOD SCI 38: 901-902

Koster, E.P. (1981) In: Criteria of food acceptance Eds: Solms & Hall 241-252

Lee, H.; Simard, R.E.; Laleye, L.C. & R.A.Holley (1983) J FOOD SCI 48: 1537-1563

Lee, W.H.; Smith, R.E.; Damare; Harris, M.E. & R.W.Johnston (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N.Skovgaard (1981) Academic Press 529pp.

Leistner, L. & W.Rodel (1976) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

Longree, K. & J.C.White (1955) J AM DIET A 31: 124-132

Lott, G. (1973) Praventivmedizin 18, 371-374

Lucke, F.-K.; Hechelmann, H. & L.Leistner (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

Luiten, L.S.; Marchello, J.A. & F.D.Dryden (1982) J FOOD PROT 45: 263-267

Luiten, L.S.; Marchello, J.A. & F.D.Dryden (1982) J FOOD PROT 45: 268-270

Lundgren, B.; Karlstrom, B. & A.-C.Ljungqvist (1979) J Sci Fd Agric 30: 305-318

Lyon, B.G. (1980) J FOOD SCI 45 (5) 1341

Mackey, B.M.; Roberts, T.A.; Mansfield, J. & G.Farkas (1980) J Hyg 85: 115-124

Matches, J.R. & J.Liston (1968a) J FOOD SCI 33: 406

Matches, J.R. & J.Liston (1968b) J FOOD SCI 33: 641-645

McLean, R.A.; Lilly, D.H. & J.A.Alford (1968) J Bact 95: 1207-1211

McDaniell, M.C.; Marchello, J.O. & A.M.Tinsley (1984) J FOOD PROT 47 (1) 23-26

Mead, G.C. (1969) J APPL BACT 32: 86-95

Mead, G.C. (1983) In: Food microbiology advances and prospects, Soc Appl Bact Symp series 11 Eds: Roberts, T.A. & F.A.Skinner Academic Press 203-214

Michener, H. & R.Elliott (1964) Advances in food research 13: 349-396

Miller, W.A. (1960) J Milk & Food Tech 23:311-314

Mills, A (1985) Proceedings of CFPRA seminar on chilled foods, 7-9th May, Stratford-upon-Avon 45-50

Minor, L.J. (1972) Cornell HRAQ 13 (1) 43-56

Minor, T.E. & E.M.Marth (1971) J Milk & Food Tech 34: 557

Minor, T.E. & E.H.Marth (1976) Staphylococci and their significance in foods. Elsevier, Amsterdam

Mintel (1981) The Mintel report on automatic vending. Mintel Publications, London

Mitsuda, H.; Kawai, F; Yamamoto, A. & K.Nakajuma (1975) J NUTR SC V 21: 151

Mossel, D.A.A. & M.A.Ratto (1973) J Food Tech

Mossel, D.A.A.; Jansma, M. & J.de Waart (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

Munce, B.A.; K.A.Buckle (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

Nicholanco, S. & M.E.Matthews (1978) J AM DIET A 72 (91) 31-37

Nie, N.H.; Hull, C.H.; Jenkins, J.G.; Steinbrenner, K. & D.H.Brecht (Eds) (1975) SPSS Statistical Package for the Social Sciences 2nd Ed McGraw-Hill

Nielsen, H.J.S. (1983) J FOOD PROT 46 (8) 693-698

Nielsen, H.J.S. & P.Zeuthen .(1984) Food Microbiology 1: 229-243

Nielsen, H.J.S. (1983) J FOOD PROT 46 (8) 693-698

NOP (1982) Attitudes to vending machines. A report on a study by NOP market research for the Automatic Vending Association of Britain NOP/8518

O'Mahoney (1982) Food Tech Nov. : 75-82

Oosterom, J.; Notermans, S. & M.D.Northolt (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, TA; Hobbs, G., Christian, J.H.B. & N.Skovgaard (1981) Academic Press 529pp.

Paradis, D.C. & M.E.Stiles (1978a) J FOOD PROT 41 (10) 811-815

Paradis, D.C. & M.E.Stiles (1978b) J FOOD PROT 41 (10) 953-956

Parekh, K.T. & M.Solberg (1970) J FOOD SCI 65: 156

Park, H.S. & E.H.Marth (1972) J Milk & Food Tecn 35: 482-488

Partnann, W (1980) Schlachten and Vermarkten 10: 305

Patterson, J.T. (1972) J APPL BACT 35: 569-575

Patterson, J.T. & P.A.Gibbs (1973) J App Bact 36: 689-697

Paul, M.E. & N.N.Potter (1978) J FOOD SCI 43: 803-808

Paulus, K.; Piekarski, J. & L.Leistner (1979) In: Advances in Catering Technology, 2nd International Symposium on Catering Systems Design. Ed: G.Glew Applied Science Publishers

PHLS (1984) Communicable disease report 84/52

Pearson, A.M.; Gray, J.I.; Wolzak, A.M. & N.A. Horenstein (1983) Food Tech 7: 121-129

Pierson, M.D.; Collins-Thompson, D.L. & Z.J.Ordal (1970) Food Tech 24: 1171-1175

Pinaga, F.; Carbonell, J.V.; Valles, S & M.Ampara Feria (1979) Revista de Agroquimica Y Tecnologiade Alimenta 19 (4) 520-532

Pivnick, H. & H.Bird (1965) Food Tech 19: 132-140

Pokorny, J.; Vozenilenilkova, B.; Kovarova, H.; Marcin, A. & J.Davidek (1982) Nahrung 26 (7/8) 689-695

Pooni, G.S. & G.C.Mead (1984) Food Microbiol 1: 67-78

Prescott, S.C. & L.P.Geer (1936) Refrig Eng 32: 211

Qvist, S. & S.Mukherji (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

Ratkowsky, D.A.; Olley, J.; McMeekin, T.A. & A.Ball (1982) J BACT 149 (1) 1-5

Riemann, H.; Lee, W.H. & C.Genigeorgis (1972) J Milk & Food Tech 35: 514

Reuter, G. (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

Rey, C.R.; Walker, H.W. & P.L.Rohrburgh (1975) J Milk & Food Tech 38 (8) 461-465

Rini, M.J.; Cremer, M.L. & J.R.Chipley (1981) J AM DIET A 78 (5) 483-489

Roberts, T.A. & G.Hobbs (1968) J App Bact 31: 75-88

Roberts, T.A.; Jarvis, B. & A.C.Rhodes (1976) J Food Tech 11: 25-40

Rowley, D.B.; Tuomi, J.M. & Westcott, D.E. (1972) US Army (Tech Rep) 72-46-FL US Army Natick Laboratories

Sakaguchi, G. (1979) Ch. 8 In: Foodborne Infections and Intoxications 2nd Ed Eds: Riemann, H. & F.L.Bryan Academic Press

Sander, E.H. & H.Soo (1978) J FOOD SCI 43: 1519

Sato, K. & H.K.Herring (1973) Proc 26th Annual Reciprocal Meat Conference 26, 64, 64-75

Sato, M. & H.Takahashi (1968) Agric & Biol Chem 32: 259

Sawyer, C.A.; Naidu, Y.M. & S.Thompson (1983) J FOOD PROT 46 (12) 1036-1043

Schiffman, S.S.; Reynolds, M.L. & F.W.Young (1981) Introduction to multi-dimensional scaling: theory, methods and applications New York Academic Press

Schmidt, C.F.; Lechnowich, R.V. & J.F.Folinazzo (1961) J FOOD SCI 26:626

Searle, G. & M.J.Crozier (1981) An investigation of low temperature food storage in large hotels in the city of Westminster City of Westminster Dept. of Environment

Shrimpton, D.H. & E.M.Barnes (1960) Chem ind 12

Schroder, D.J. & F.F.Busta (1973) J Milk & Food Tech 36: 189

Schutz, H.G. (1971) Food Tech 25 (3) 53

Seideman, S.C.; Vanderzant, C.; Smith, G.C.; Hanna, M.O. & Z.L.Carpenter (1976) J FOOD SCI 41: 738-742

Seideman, S.C.; Carpenter, Z.L.; Smith, G.C.; Dill, C.W. & C.Vanderzant (1979a) J FOOD PROT 42: 317-322

Seideman, S.C.; Smith, G.C.; Carpenter, Z.L.; Dutson, T.R. & C.W.Dill (1979b) J FOOD SCI 44: 1036-1040

Shaw, B.G. & R.H.Dainty (1985) In: Food group symposium shelf-life of red meat, fish and poultry J Sci Food Agric 36: 122-128

Shaw, M.K. & D.J.Nicol (1969) In: 15th European Meeting of Meat Research Workers, Helsinki 226-232

Shaw, B.G. & J.B.Latty (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N.Skovgaard (1981) Academic Press 529pp.

Shay, B.J.; Grau, F.H.; Ford, F.L.; Egan, A.F. & D.Ratcliff (1978) Food Tech Aust 30: 48-54

Sheard, J.B. (1983) Environ Health 91 (2) 31-37

Shelton, A. & P.Ainswoth (1981) Hospitality 6: 21-25

Shrimpton, D.H. & E.M.Barnes (1960) Chem Ind Dec 3

Sidel J.L. & H.Stone (1976) Food Tech 30 (11) 32-38

Sidel, J.L. & H.Stone (1983) Food Tech Nov. 36-38

Silla, H. & B.Simonsen (1985) Fleischwirtschaft 65 (1) 66

Silliker, J.H.; Woodruff, R.E.; Lugg, J.R.; Woolfe, S.K. & W.D.Brown (1977) Meat Science 1: 195

Silliker, J.H. & S.K.Woolfe (1980) Food Tech 34 (3) 59

Simard, R.E.; Lee, B.H.; Laleye, C.L. & R.A.Holley (1983a) J FOOD PROT 46: 188

Simard, R.E.; Lee, B.H.; Laleye, C.L. & R.A.Holley (1983b) J FOOD PROT 46: 199

Simunovic, J.L.; Oblinger, & J.P.Adams (1985) J FOOD PROT 48 (3) 265-276

Skinner, W.E.D. (1985) Director of the Automatic Vending Association of Britain Pers Comm

Skirrow, M.B. (1982) J Hyg Camb 89 (2) 175-184

Slabyj, B.M.; Dollar, A.M. & J.Liston (1965) J FOOD SCI 30: 344-350

Smith, M.G. (1985) J Hyg 94: 289-300

Smith, J.L.; Buchanan, R.L. & S.A.Palumbo (1983) J FOOD PROT 46 (6) 545-555

Snedecor, G.W. & W.G.Cochran (1967) Statistical Methods 6th Ed Iowa Stat University Press

Snyder, P.O. & M.E.Matthews (1984) J FOOD PROT 47: 876-885

Solberg, M. & B.Elkind (1970) J FOOD SCI 35: 126

Solomon, H.M.; Kautter, D.A. & R.K.Lynt (1982) J FOOD PROT 45: 516-518

Spahl, A.; Reineccius, G. & S.Tatini (1981) J FOOD PROT 44: 670-673

Stanley, G.; Shaw, K.J. & E.F.Egan (1981) Appl Environ Microb 41 (3) 816-818

Steinke, P.K.W. & E.M.Foster (1951) Food Res 16: 372-376

Stern, N.J.; Hernandez, M.P.; Blankenship, L.; Diebel, K.E.; Doores, S.; Doyle, M.P.; Ng, H.; Pierson, M.D.; Sofos, J.N.; Sveum, W.H. & D.C.Westhoff (1985) J FOOD PROT 48 (7) 595-599

Stier, R.F.; Bell, L.; Ito, K.A.; Shafer, B.A.; Brown, L.A.; Seeger, M.L.; Allen, B.H.; Porcuna, M.N. & P.A.Lerker (1981) J FOOD SCI 46, 1639-1642

Stiles, M.E. & L.-K.Ng (1979a) J FOOD PROT 42 (6) 464-469

Stiles, M.E. & L.-K.Ng (1979b) J FOOD PROT 42 (6) 624-630

Stiles, M.E.; Ng, L.-K. & D.C.Paradis (1979) CAN I FOOD 12: 128-130

Stone, H.; Sidel, J.H. & J.Bloomquist (1980) CEREAL F W 25: 642-644

Stone, H.; Sidel, J.; Oliver, S.; Woolsey, A & R.C.Singleton (1974) Food Tech 28 (11) 24-34

Strong, D.H. & J.C.Canada (1964) J FOOD SCI 29: 479-482

Strong, D.H. & N.M.Ripp (1967) APPL MICROB 15: 1172-1177

Sutton, R.G.; Kendall, M. & B.C.Hobbs (1972) J Hyg 70: 415-424

Syariéf, H.; Hamann, D.D.; Giesbrecht, F.G.; Young, C.T. & R.J.Young (1985) J FOOD SCI 50: 631-650

Szczesniak, A.S. & E.L.Kahn (1971) J Textural Studies 2: 280-295

Tanner, F.W.; Beamer, P.R. & C.J. Rickher (1940) Food Res 5: 323

Tatini, S.R. (1973) J Milk & Food Tech 36: 559-563

Thatcher, F.S. & D.S.Clark (1968) Micro-organisms in foods Vol 1 Canada: Universtiy of Toronto Press

Thatcher, F.S.; Robinson, J. & I.Erdman (1962) J APPL BACT 25 (1) 120-124

Thomas, Y.O.; Kraft, A.A.; Rust, R.E. & D.K.Hotchkiss (1984) J FOOD SCI 49: 1367-1371

Tiedeman, W.D. (1958) Am J Public Health 48: 854

To, E.C. & M.C.Robach (1980) J Food Tech 15: 543-547

Tompkin, R.B. (1973) Food Tech 12

Toule, G. & O.Murphy (1978) J Hyg 81: 161-169

Traci, P.A. & C.L.Duncan (1974) APPL MICROBIOL 28: 815-821

Trakulchang, S.P. & A.A.Kraft (1977) J FOOD SCI 42: 518-521

Tuck Shoppe (1982) Company literature.

Turnbull, P.C.B. & P.Rose (1982) J Hyg Camb 88: 29-37

Tuomi, S.; Matthews, M.E. & E.H.Marth (1974) J Milk & Food Tech 37 (10) 494-498

Uebersax, M.A.; Dawson, L.E. & K.L.Uebersax (1978) POULTRY SCI 57: 660

Unklesbay, N.F.; Maxcy, R.B.; Knickrehn, M.E.; Stevenson, K.E.; Cremer, M.L. & M.E.Matthews (1977) North Central Regional (Res Pub) No 245 Colombia: Missouri Agric Exp Sta

Valuenauela, S.; Nickerson, J.T.R.; Campbell, C. & S.A.Goldblith (1967) In: Botulism 1966 Eds: Ingram, M. & T.A.Roberts Chapman & Hall, London

Walker, H.W. (1975) Crit Rev Food Sci Nutr 7: 71-104

Wauters, G. (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

White, A. & B.C.Hobbs (1963) ROY SOC HEA 83: 111-114

Wodzinski, R.J. & W.C.Frazier (1961) J Bact 5 (81) 401-408

Woodburn, M. & Kim, Chung H. (1966) APPL MICROB 14: 914-920

Wolfe,S.K. (1980) Food Tech 34 (3) 55

Zaleski, S.J. (1981) In: Psychrotrophic microorganisms in spoilage and pathogenicity. Eds.: Roberts, T.A.; Hobbs, G., Christian, J.H.B. & N Skovgaard (1981) Academic Press 529pp.

Zallen, E.M.; Hitchcock, M.J. & G.E.Goertz (1975) J AM DIET A 67: 552-557

Zamora, M.C. & N.E.Zaritzky (1985) J FOOD SCI 50: 1003-1006

APPENDIX 1

THE QUESTIONNAIRE EMPLOYED IN THE SURVEY OF THE VENDING INDUSTRY

The development of vending in your organization

1. Is vending the main function of your organization or is it subsidiary?

2. Since when have you been involved in:

   Beverage vending
   Long life snacks
   Chilled foods

3. What percentage of your vending operations do these areas make up?

   Beverage vending
   Long life snacks
   Chilled foods

The vended product

1. Please give examples of your vended food menu.

2. Briefly describe your method of prroducing these menu items.

3. How long is the shelf-life of your menu items from the time they are produced?

4. How long do they remain in the vending machine?

5. What percentage food waste do you have (vended foods not sold)?

The vending equipment

1. What make and model of equipment do you use?

	Manufacturer	Model	Number in use
Beverages			
Chilled food vending machines			
Microwaves			

2. Does it meet your requirements and if not why not?

Problems

1. Which of the following problems do you encounter and how are they dealt with?

Customer resistance to vended service

Breakdown of equipment

Queuing at machines

Wastage

Menu fatigue

Additional comments

APPENDIX 2

THE PREPARATION OF COOKED MENU ITEMS FOR USE IN THE PILOT MICROBIOLOGY EXPERIMENT.

1. Preparation of cottage pie

The ingredients in the cottage pie are shown in Table A.2.1. The mashed potato was prepared by placing the peeled potatoes and salt in a pan of cold water, bringing them to the boil and simmering for 20 minutes or until the potatoes were cooked. The potatoes were drained and passed through a sieve to mash them. The butter was mixed in.

For the meat mixture the onions were fried in the butter in a heavy based pan over a medium gas flame on a Benham six gas burner hob until transparent. The mixed beef was added to the pan and stirred until browned (3 - 5 minutes). The beef stock and seasoning was mixed into the meat mixture and it was brought to the boil and simmered for 40 minutes.

Cottage pies were made in individual stainless steel containers and consisted of 100g of meat mixture, topped with 75g mashed potato spread evenly with a fork. The potato layer of the pies was browned by placing the pies under a hot grill for two minutes. The finished pies were chilled in a Foster blast chiller for 90 minutes.

Table A.2.1 Cottage pie ingredients

Mashed potatoes	
1.5 Kg	Peeled potatoes
5 g	Salt
Meat mixture	
75g	Butter
370g	Peeled diced onions
1.4 Kg	Minced beef
400mls	Beef stock
5g	Salt
2g	Pepper

2. Preparation of roast chicken under simulated conditions of food preparation.

Frozen chickens were defrosted overnight at room temperature (between 15 and 20°C) and were washed under cold, running water. The chickens were patted dry with absorbent paper towelling, placed on greased roasting trays, brushed with melted butter and roasted at 190°C in a Benham convection oven. Chickens were assumed cooked when the internal temperature between the leg and thigh joint and in between the area adjoining the leg and thigh to the body was greater than 80°C. On removal from the oven, the chickens were immediately cut into 5 portions (2 legs, 2 wings and 1 breast portion), which were placed in individual polypropylene containers and put into a Foster blast chiller for 90 minutes.

3. Preparation of roast chicken under actual food preparation conditions in a local hospital.

Chickens were prepared and roasted in a hospital kitchen to determine whether preparation under actual conditions differed from preparation under simulated conditions. The method of preparing the chickens prior to roasting has been described above. The chickens were cooked in a Benham gas oven, type number T207/1A on its maximum heat setting. A digital thermometer recorded an operating temperature of 180°C. The chickens were cooked until their internal temperatures at the sites specified above exceeded 77°C. The chickens were portioned, placed in containers and wrapped in cling film.

APPENDIX 3

A REVIEW OF THE GROWTH CHARACTERISTICS OF THE MAJOR FOOD POISONING ORGANISMS.

Bacterial food poisoning can be defined as acute gastro-enteritis resulting from the ingestion of food containing pathogenic bacteria and/or their toxins. Two types are generally recognized; the intoxication type in which the food poisoning toxin is pre-formed in the food (eg staphylococcal food poisoning, botulism) and second the infection type in which the viable bacteria present in the foods are the food poisoning agents and the food poisoning toxins are produced by the organisms in the intestinal tract of the victim (eg salmonellae food poisoning and Clostridium perfringens food poisoning).

1. Staphylococcus aureus

The general characteristics and properties of Staphylococcus aureus related to food have been reviewed and discussed by Minor and Marth (1976) and Smith et al., (1983). It is well established that Staphylococcus aureus can grow in conditions that do not favour enterotoxin production, although toxin production has been observed in experimental resting cultures (from Smith et al., 1983)

1.1. Effect of temperature on growth

Growth of Staphylococci occurs in the range 7 - 47.8°C and, more importantly, toxin production between 10 and 46°C (Tatini, 1973). Their optimum growth temperature is between 37° and 40°C and for production of toxin between 40 and 45°C.

According to Jackson (1974), metabolism occurring at sub-minimal temperatures will be 'unbalanced', which may cause metabolic injury. He observed metabolic injury of

Staphylococcus aureus after exposure to 5°C for 21 days. The injury was manifested as a progressive loss of ability to form colonies on mannitol salt agar.

Several investigators have found that numbers of Staphylococci decrease slowly during frozen storage (Jones and Lockhead, 1939; Farrell and Upton, 1978; Genigeorgis and Riemann, 1979). In contrast, Kereluk et al. (1962) found that counts of Staphylococcus aureus at 5°C dropped off during the 30 day storage period, while the counts at 0° and -12°C remained constant. The numbers of Staphylococcus aureus in beef loaves held at 5°C decreased during storage for 24, 48 and 72 hours (Bunch et al., 1977).

The lowest temperature for growth of Staphylococcus aureus in foods was found by Angelotti et al., (1961) who examined growth of Staphylococcus aureus in custard, ham salad and chicken a la king with respective pH values of 6.6, 5.6 and 6.2. The autoclaved foods were inoculated with 8 strains of Staphylococcus aureus to a level of 10^7 /g and incubated for 5 days between 4.2° and 35°C. In custard and chicken a la king the staphylococci grew at temperatures of 6.8°C and above. In ham salad no growth was observed from 4.2° to 10°C. This latter result may have been due to the reduced pH, which was a result of the addition of salad dressing. This would agree with a more recent study on the fate of Staphylococcus aureus in meat salads prepared with mayonnaise, where it was found that mayonnaise retards the growth of Staphylococcus aureus due to its low pH (Doyle et al., 1982). Farrell and Upton (1978)reported a significant increase of Staphylococcus aureus from 10^6 to 10^7/g in bacon stored at 5°C for 28 days. Even though this result was significant the initial level of inoculum was high and a tenfold increase in numbers occurred very slowly and growth at this temperature has not been reported by other investigators.

Elliott (1963) visually observed the minimum growth temperature of Staphylococcus aureus (SG8A) in trypticase soy

agar to be 14.3 °C, after 14 days in a temperature gradient incubator.

More important than the growth of Staphylococcus aureus at low temperatures, is the production of enterotoxin. Although Staphylococcus aureus can grow well below 20 °C, toxin production is impaired below this temperature. McLean et al. (1968) reported that only small amounts of enterotoxin B were produced at 16° and 20°C (10-20 ug/ml versus 340 ug/ml at 37°C), even though growth was almost equivalent to that at 37°C. Several investigators have shown that enterotoxin production can occur in certain foods at temperatures as low as 10°C (Genigeorgis et al., 1969; Tatini, 1973). The production of enterotoxins in laboratory media has been reviewed by Bergdoll (1979).

1.2 Effect of microbial competition on growth.

Many studies have shown that Staphylococcus aureus is unable to compete with normal foodborne bacteria; this subject has been reviewed by Minor and Marth(1971) and Genigeorgis (1973). The effect of microbial competition may increase the minimum temperature for growth. For example, Staphylococcus aureus grew well in sterilized meat at 12°C, but was inhibited or grew poorly in unsterilized meat (Slabyj et al 1965).

Bacteria known to be antagonistic to Staphylococcus aureus include; Acinetobacter, Aeromonas, Bacillus, Enterobacteriaceae, Lactobacilli, Pseudomonas, Streptococci and Staphylococcus epidermidis (Bergdoll, 1979).

1.3. Effect of atmosphere on growth.

Staphylococci can grow and produce enterotoxins under anaerobic as well as aerobic conditions, although growth is slower anaerobically (Thatcher et al., 1962; Christiansen and

Foster, 1965; Genigeorgis et al., 1969). Also the amount of enterotoxin A and B produced anaerobically is considerably less than that produced aerobically (McLean, 1968).

The anaerobic growth of staphylococci in foods is limited by the competition from other bacteria, mainly lactic acid bacteria that are favoured by the lower oxidation-reduction potential (Ingram, 1962; Christiansen and Foster, 1965). Silliker and Woolfe, (1980) reported that Staphylococcus aureus was unable to grow at $10^{o}C$ over ten days in raw ground beef stored in air, carbon dioxide with and without carbon monoxide. The authors concluded that staphylococci were poor competitors.

To and Robach (1980) reported the growth of Staphylococcus aureus in cooked uncured vacuum packed turkey products stored at $15^{o}C$, from 10^{3} per gram of meat to 10^{8} per gram of meat within 6 days.

The gas permeability of packaging film had little effect on the growth of Staphylococcus aureus in vacuum packed bologna type sausage, in which Staphylococcus aureus was able to grow at $8^{o}C$ but not at $5^{o}C$ (Nielsen and Zeuthen, 1984). Sandwiches packed in a nitrogen atmosphere and inoculated with Staphylococcus aureus did not become toxic at 8 or $12^{o}C$ after 31 days storage. At $26^{o}C$ sausage and hamburger sandwiches became toxic within 2 and 4 days respectively (Bennett and Amos, 1982).

According to Smith et al., (1983) there has been little work on the effect of CO_2 levels greater than 5 % on the growth and toxin production of Staphylococcus aureus.

2. Clostridium Botulinum

Botulism is caused by the consumption of food containing neurotoxin produced by Clostridium botulinum. The organism is harmless if ingested in the detoxified spore condition, it is

only when the spores germinate and the cells autolyse that toxin production takes place (Prescott and Geer, 1936). Seven types of toxin, A through to G are known. The strains are frequently divided into three general groups, based on cultural and physiological characters (Frazier and Westhoff, 1978). Groups 1 (all type A strains and proteolytic strains of B and F) and 2 (type E and non proteolytic strains of B and F) cause human botulism, while group 3 is responsible for animal botulism. Type G has been isolated from soils but has not been implicated in human botulism, while type F has caused botulism only twice.

Hobbs (1981) reviews the taxonomy and ecology of Clostridium botulinum. The epidemiology of botulism has been reviewed by Sakaguchi (1979).

Clostridium botulinum appears to be more common in pork than in lamb or beef and must be expected to occur from time to time in pork products, although normally the number of spores per gram will be very low (Roberts et al., 1976). The incidence of Clostridium Botulinum spores in meat products in the US has been reviewed by Simunovic et al., (1985). They concluded that incidence of Clostridium botulinum is very low and that the incidence of non proteolytic strains in meats and meat products is largely unknown and uninvestigated. Clostridium botulinum type E is restricted to aquatic, nutritionally rich habitats, thus a high percentage of fish throughout the world are contaminated (Huss, 1981; Zaleski, 1981). Food poisoning due to the consumption of smoked or marinaded fish is very rare. This suggests that food poisoning outbreaks from Clostridium botulinum type E result not only from mistakes in fish processing but also from particularly heavy contamination of individual fish (Zaleski, 1981).

2.1. Effect of temperature on growth.

Clostridium botulinum type E and non proteolytic strains of types B and F are capable of growth at temperatures as low as 3 - 4°C (Schmidt et al., 1961; Abrahamsson et al., 1965; Eklund et al., 1967). The optimum growth temperature of Clostridium botulinum is 37°C for types A and B strains and 30°C for type E strains. Simunovic et al., (1985) reviews the growth and toxin production of Clostridium botulinum at refrigeration temperatures.

The lowest reported growth temperature of Clostridium botulinum in foods is that of type E, which grew at 3.3°C in a heat sterilized stew substrate within 31 - 45 days (average of 36 days). Toxin production and visible outgrowth, as evidenced by gas formation occurred (Schmidt et al., 1961). Non proteolytic Clostridium botulinum type B and F of marine origin grew at 3.3°C in cooked meat medium (Eklund et al., 1967). According to Zaleski et al., (1981) the higher the number of type E cells present, the more rapid are growth and toxin production. The introduction of 10^6 cells of Clostridium botulinum type E into herring intestines caused toxin production after 24 hours at 5.5°C.

In general, type E and non proteolytic type B and F strains have minimum growth temperatures about 10 degrees lower than A and B strains (Prescott and Geer, 1936). Ohye and Scott (1953)found that actively growing type A and B cells could initiate growth as low as 12.5°C, but not at 10°C, while the lowest temperature at which spore inocula could germinate and grow was 15°C. Tanner et al., (1940) reported growth and toxin production of Clostridium botulinum type A in meat and type B in vegetables at 10°C but not at 5°C, following inoculation with spores. Clostridium botulinum type C produced toxin in fruit at 15°C but not at 10°C.

The toxin is able to survive freezing, but is relatively heat sensitive. In vacuum packed smoked fish type E toxin was

destroyed after 5 minutes at 65°C (Georgala and Hurst, 1963).

2.2. Effect of microbial competition on growth

The effect of microbial competition on the growth of Clostridium botulinum has been reviewed by Genigeorgis and Riemann (1979). A synergistic effect of lactic acid bacteria on Clostridium botulinum has been observed by Benjamin et al., (1956), who suggested that it may be due to a reduction in the oxidation-reduction potential or to the production of growth factors.

Streptococcus lactis and Lactobacillus viridescens seemed to inhibit or delay toxin production (Valenzuela et al., 1967). The main factor in this 'natural' inhibition of Clostridium botulinum appears to be a reduction in pH caused by contaminants. Riemann et al (1972) examined the effect of adding 1 percent glucose to commercially produced semi-preserved meat products on the growth of Clostridium botulinum and Staphylococcus aureus . In most instances, the glucose addition resulted in the natural flora producing acid which caused a drop in pH to less than 5.3 in 4 days of incubation at 20°C, which inhibited Clostridium botulinum.

Filtrates of Clostridium sporagenes cultures and to some extent filtrates of Streptococcus faecalis and E.Coli cultures may have an inhibitory effect on Clostridium botulinum spore germination and proteolytic enzymes from Clostridium sporagenes may destroy botulinum toxin (Genigeorgis and Riemann, 1979). Pseudomonas fragi and Pseudomonas fluorescens facilitated the production of type E toxin in fish tissue incubated under aerobic conditions at 7.2°C. However, with either organism together with Clostridium botulinum type E by the time toxin was produced the tissues were considered spoiled because of growth of the aerobic bacteria.

2.3. Effect of atmosphere on growth

The extension of shelf-life by modifying a products storage atmosphere is well established. However, there is the danger that Clostridium botulinum growth and toxin production may occur prior to food spoilage, in particular with the non proteolytic strains, as the activities of common spoilage organisms are minimized. Heating the foods prior to consumption will render any toxin present harmless and so the greatest potential risk lies with foods stored under vacuum or modified atmosphere that are not heated before consumption, such as kipper fillets or smoked salmon. Many of the outreaks of type E botulism in the U.S.A. between 1961-63, due to smoked fish have been attributed to the use of vacuum packaging (Hobbs et al., 1969) . However, it is now known that vacuum packaging itself only slightly increases the rate of toxin production in contaminated fish.

Christiansen and Foster (1965) attempted to determine whether conditions of vacuum packaging may increase the opportunity for growth of Clostridium botulinum type A. Sliced bologna was inoculated with spores of Clostridium botulinum type A and packaged with and without vacuum and stored at 37°, 30° and 22°C. Toxin was detected as quickly in non evacuated packs as vacuated packs. However, there was evidence that vacuum packing may accelerate toxin production at first, but the effect was not great.

Pivnick and Bird (1965) found packaging in air impermeable pouches affected spoilage but not toxigenesis in vacuum packed cooked meats. Toxigenesis at 30°C was affected by size of inoculun, temperature of storage, type of Clostridium botulinum and the nature of the meat product at 30°C.

Toxin production by Clostridium botulinum types A, B and E in vacuum packed potatoes was examined by Notermans et al (1981). The inoculated potatoes were vacuum packed in foil

pouches, heated in a water bath at 95°C for 40 minutes and cooled in running tap water at 2°C for 30 minutes. Approximately 10^6 spores of types A, B and E were inoculated into pouches prior to evacuation. The pouches were stored at 4°, 10°, 15° and 20°C. Uninoculated samples were used to evaluate shelf life. After 8 days at 10°C small amounts of types A and B toxin were detected. After 9 days type E toxin was detected and the amount increased with further storage. At 4°C toxin production by all types was prevented, even when type E spores were added after the cooking process. This method of preparing potatoes assumed that the relatively heat stable proteolytic Clostridium botulinum (types A and B) would survive heating but would not be able to grow at refrigeration temperatures, whereas the non proteolytic strains able to grow at low temperatures would be destroyed during heating. However, they were able to survive the heat treatment employed, which was attributed to the protective effect of the potatoes.

Stier et al (1981) examined the effect of modified atmosphere storage on the growth of Clostridium botulinum in salmon fillets. Samples of fillets inoculated with type A, B and E spores were stored at 4.4° and 22.2°C in 60% CO_2, 25% O_2 and 15% N_2, while controls were stored in air at the same temperatures. At 4.4°C no toxigenesis was observed in the modified atmosphere or air over a 57 day period. The air held samples were obviously spoiled after 6 days, whereas those held under modified atmospheres were of an excellent appearance. At 22.2°C all inoculated samples were toxic within 2-3 days. Spoilage generally preceded toxigenesis. The interval between toxigenesis and spoilage apparently decreased with increased storage temperature.

The possibility of food poisoning prior to food spoilage in frozen-gas-packed sandwiches available on the retail market in USA was examined by Kautter et al.,(1981). Three varieties of nitrogen packed sandwiches (turkey on wheat bread, fresh sausage on biscuit and hamburger on a roll) were

thawed and inoculated with Clostridium botulinum types A, B and E spores. The sandwiches were then stored in a nitrogen atmosphere at either 26°, 12° or 8°C. At 8° and 12°C there was no evidence of type A and B toxin in any of the inoculated sandwiches after 30 and 60 days of storage. At 26°C types A and B toxin production occurred, after 4 days in the hamburger, while it was still fully acceptable. Sausage and turkey sandwiches did not become toxic after 30 or 60 days at 12°C. At 8°C none of the sandwiches became toxic. Sandwiches stored in air were all obviously decomposed before toxin was produced.

3. Clostridium perfringens

Foodborne illness caused by Clostridium perfringens has been reviewed by Walker (1975). Six types of the organism are recognised based upon their ability to produce exotoxins; A through to F, which refers to the predominant antigen produced by the organism (Craven, 1980). The food poisoning strains are primarily type A, which also includes the classical gas gangrene strains.

The causative factor of the food poisoning is an enterotoxin, which is synthesized by sporulating cells in association with the late stages of sporulation. The potential for sporulation in cooked food stuffs is poor and if formed at all is unlikely to be detected or to be in sufficient quantity to initiate symptoms (Hobbs, 1979).

Clostridium perfringens is ubiquitous in nature and is found in soils, water, food, dust, spices and the intestinal tract of man and other animals. Red meats and poultry products are usually involved in outbreaks of Clostridium perfringens food poisoning. Raw boneless beef yielded Clostridium perfringens in 30% of the samples obtained from a fast foodservice restaurant (Bryan and Kilpatrick, 1971). Vegetative cells of Clostridium perfringens were present in 50% of 32 retail samples of frozen precooked beef and poultry items and about

15% of samples demonstrated spores of Clostridium perfringens (Trakulchang and Kraft, 1977). Hall and Angelotti (1965) found 20 out of 101 samples of processed meats and meat dishes contained viable Clostridium perfringens cells. Only 2 of the 113 isolates were shown to produce heat resistant spores which indicates that their presence in the samples was due principally to contamination of the food with viable spores or cells after cooking. Other foods that have been implicated include fish, shrimp, crab, beans, potato salad, macaroni cheese and olives (Craven, 1980).

Large amounts of food, subjected to a prolonged period of cooling (often overnight) and unrefrigerated storage are usually implicated as causative factors in outbreaks (Hobbs, 1979). The effect of the post cooking holding temperature of foods on Clostridium perfringens is reviewed by Craven (1980).

Protein supplementation of food products may influence the growth of Clostridium perfringens. The addition of soy meat or protein additives to beef in meat loaves in actual processing conditions did not affect the growth of Clostridium perfringens, however the beef itself was an excellent growth medium. The addition of protein additives to turkey meat loaves significantly enhanced the rate of growth of Clostridium perfringens. Of 16 ingredients used, synthetic 'soy beef' beef like flavour (hydrolysed plant protein), cornflour, cocoa and vegetable oil stimulated the growth of Clostridium perfringens (Schroder and Busta, 1973). In autoclaved beef, chicken or turkey media, substitution of half the meat protein with cottonseed protein reduced the growth rates, while substitution with soy protein did not affect the growth rates. The carbohydrate fraction of cotton seed was thought to retard growth rates (Kokoczka and Stevenson, 1976).

3.1. Effect of temperature on growth

The minimum growth temperature of Clostridium perfringens in bacterial media is 15°C (Rey et al., 1975; Roberts and Hobbs 1968). In previous unpublished experiments Roberts had repeatedly failed to grow Clostridium perfringens in vacuum packed fresh beef at 15°C under conditions supporting growth at higher temperatures.

Of six strains of Clostridium perfringens none were able to initiate growth at 5°C, four of the six strains were unable to grow at 15°C, while at 22°C only one strain did not grow. All strains formed spores between the temperatures of 32° - 40°C, but only one strain was able to form spores below this range (27°C) (Rey et al., 1975). In heat processed vacuum packed frankfurters, surviving vegetative cells increased from 10^3 per gram to 10^6 per gram in three days at 15°C (Solberg and Elkind, 1970). Refrigerated and frozen storage produces a lethal effect on Clostridium perfringens vegetative cells and spores. Traci and Duncan (1974) reported that a progressive loss of viability occurred in cold shocked Clostridium perfringens with increased time of low temperature exposure. As many as 75% of viable cold shocked cells suffered injury when exposure occurred late in the exponential phase of growth.

Strong et al., (1966) reported the survival of 1 - 30% of Clostridium perfringens cells and 41 - 76 % spores in starch pastes after 180 days refrigerated storage. The number of Clostridium perfringens in raw beef declined upon storage at temperatures between 1 and 12.5°C (Goepfert and Kim, 1975).

The survival of Clostridium perfringens in chicken a la king, codfish in cream sauce and broccoli in cream sauce was compared in two food processing systems: frozen storage at -22°C and the Nacka system (vacuum packing, followed by pasteurization and storage at 2°C). After 15, 30 and 45 days, samples from both treatments gave negative results for

Clostridium perfringens, which confirmed the known lethality of freezing on Clostridium perfringens (Kossovitsas et al., 1973). Survival of Clostridium perfringens during storage at low temperatures appears to vary with strain, numbers of vegetative cells and spores and substrate (Tuomi et al., 1974).

The behaviour of a food poisoning strain of Clostridium perfringens in both raw and heated meat at temperatures from -20° to 37°C was studied by Barnes et al.,(1963). In beef stored at 1°, 5°, 10°, and 15°C for 13 days there was no multiplication, but a slow destruction of vegetative cells and little change in the spore count. At 20°C multiplication was slow, but was rapid at 25° and 37°C . No growth of Clostridium perfringens occurred in cooked meat after 7 days at 6.5°C (White and Hobbs, 1963). The numbers of Clostridium perfringens in raw beef packed in cellophane and saran wrap declined upon storage at temperatures between 1° and 12.5°C (Goepfert and Kim, 1975).

Survival of Clostridium perfringens spores in cooked meats has been observed by several investigators (White and Hobbs, 1963; Barnes et al., 1963; Strong and Ripp, 1967; Woodburn and Kim, 1966; Sutton et al., 1972; Rey et al. (1975) reported that strains of Clostridium perfringens that sporulated poorly were found to have the highest heat resistance of those tested (95°C for three hours), while strains producing greater numbers of spores had lower survival times (less than 10 - 35 minutes at 95°C).

Spores of Clostridium perfringens can also survive in frozen foods (Trakulchang and Kraft, 1977; Strong and Canada, 1964).

3.2. Effect of microbial competition on growth.

Clostridium perfringens is generally a poor competitor with the natural flora found in food products. It is

adversely affected in associative growth with Lactobacillus acidophilus, Streptococcus diacetilactis, Streptococcus faecalis var zymogenes and Streptococcus faecalis (Craven, 1980). Although total anaerobic counts increased considerably in egg products at 12°, 20° and 30°C, inoculated Clostridium perfringens were outgrown by the natural flora (Paul and Potter, 1978).

3.3. Effect of atmosphere on growth.

Cooking food creates a substrate more favorable to Clostridium perfringens growth by driving off O_2 and lowering the oxidation-reduction potential (Eh). Clostridium perfringens is not as sensitive to O_2 as many other anaerobic bacteria (from Craven, 1980). The Eh requirements for Clostridium perfringens, depending on the pH and medium, may range from +31 to +230 mV, which may explain its ability to grow in foods that are not appreciably anaerobic (Genigeorgis and Riemann, 1979). Once growth begins, Clostridium perfringens produces metabolites which lowers the Eh and while in the log phase grows uninhibited even in the presence of atmospheric oxygen (Craven, 1980).

Differences in the effect of CO_2 and N_2 on germination of Clostridium perfringens were found by Enfors and Molin (1978). In 100% N_2 spores of Clostridium perfringens germinated slowly or not at all at 37°C, whereas in CO_2 germination was rapid. The stimulatory effect of CO_2 on germination was greatest at pH values of less than 6·0. Hyperbaric pressures of CO_2 (25 atm.) inhibited the germination of Clostridium perfringens spores.

Parekh and Solberg (1970) found no significant difference in the generation times of individual strains of Clostridium perfringens in fluid glycollate medium, flushed with either 100% CO_2 or N_2 gas at atmospheric pressure and incubated at 43°C. However, between strains there was a significant difference in growth rates.

4. Salmonellae

All species and strains of Salmonella may be presumed to be pathogenic for man and the disease syndromes, collectively known as salmonellosis, may be divided into clinical types. Salmonella typhimurium causes typhoid fever, which is the most severe of all diseases caused by this genus. The paratyphoid fevers are caused by Salmonella paratyphimurium A, Salmonella paratyphimurium B, Salmonella paratyphimurium C and others. Gastroenteritis is the third disease caused by Salmonella species (Jay,1978).

4.1. Effect of temperature on growth.

The optimum growth temperature of Salmonella is from 35 to 37^{o}C. During freezing the numbers of Salmonella in foods gradually decline but some cells are able to survive (Kossovitsas, 1973; Farrell and Upton,1978; Bryan et al, 1979). According to Georgala and Hurst (1963) Salmonella survive better at -20^{o}C than 2^{o}C. However, Salmonellae will persist (although at a reduced level) throughout the refrigerated storage life of foods (Goepfert and Chung, 1970; Davidson and Webb, 1973; Stiles and Ng, 1979).

The minimum growth temperature of salmonellae varies with the type of strain and the substrate. The lowest reported growth temperature in bacterial media was reported by Matches and Liston (1972b). Salmonella heidelburg grew on the surface of trypticase soy agar at 5.2^{o}C within 7 days.

Matches and Liston (1968b) used a temperature gradient incubator to obtain the minimum growth temperatures of salmonellae serotypes. Between the temperatures 1.1^{o}C and 4.3^{o}C cell numbers declined. After a lag period of 5 days, Salmonella heidelburg increased in numbers at 5.9^{o}C ;

whereas at 5.1°C and below numbers declined. Salmonella derby grew at 7.5°C after a 12 day lag period, but declined in numbers at 6.7°C and below. Salmonella typhimurium grew at 5.9°C after a lag of 26 days.

The growth of salmonellae serotypes in sterilized custard, ham salad and chicken a la king at temperatures between 4.2° and 35°C was examined by Angelotti et al. (1961). A mixed culture of Salmonella seftenburg, Salmonella enteritidis and Salmonella manhattan, was inoculated into the sterile samples. In custard (pH 6.6) and ham salad (pH 5.6) the salmonellae underwent a gradual decline in numbers at all temperatures from 4.4° to 10°C. In chicken a la king there was no significant change in numbers over 5 days at 4.2° and 5.5°C, whereas at 6.7°C numbers began to increase after 4 days and at 7.7° and 9.0°C salmonellae grew more rapidly than Staphylococcus aureus in similar experiments.

Shaw and Nicol (1969) reported growth of Salmonella oranienburg at 8 ° C (35 hour generation time) on sterile beef slices, but not at 7°C in tryptose phytone yeast extract broth.

The minimum growth temperature of salmonellae in the presence of a competing flora are generally higher than when no other organisms are present. Mackey et al., (1980) reported the minimum recorded mean gereration times of a number of salmonellae serotypes to be 8.1 hours at 10 °C, 5.2 hours at 12.5°C and 2.9 hours at 15°C, when grown on beef from a commercial abbatoir. Growth did not occur at 7-8°C. Growth on minced beef has been reported at 12.5°C, but not at 7°C (Goepfert and Kim, 1975) and on minced pork at 10°C, but not at 4°C (Alford and Palumbo, 1969). Both these meats carried their normal microflora.

Salmonella isolated from a food poisoning outbreak was unable to grow in rehydrated skimmed milk stored at 5°C

over 5 days; at 10°C growth occurred after 5 days storage (Julseth and Diebel, 1969).

Salmonella heidelburg was able to grow in competition with the naturally occuring microflora of english sole at 8°C but not at 6°C (Matches and Liston, 1968a).

The various serotypes and strains of salmonellae have almost the same resistance to heat, with the exception of Salmonella seftenberg 775W, which is 10 to 20 times more heat resistant in liquid media or moist foods. Samples of meat containing 3 x 10^8 Salmonella typhimurium per gram of sample contained no viable cells after exposure for five minutes at 60°C. Similar samples inoculated with Salmonella seftenburg 775W required an exposure from 10 - 15 minutes at 65°C to kill an equivalent number of cells (Bayne et al., 1965).

4.2. Effect of microbial competition on growth.

In pure cultures salmonellae are able to increase in numbers more rapidly and initiate growth at lower temperatures than when grown in competition with other micro organisms. Salmonellae were able to grow in sterile crabmeat slurry at 8°C to a level of 10^8/g of sample in 14 days, but where microbial competition was present the numbers of salmonellae declined at 11°C and below (Matches and Liston, 1968a).

The growth of salmonellae were inhibited by reduced pH in bologna caused by growth of lactic acid bacteria stored at 21 and 30°C for 25 hours. Where numbers of lactic acid bacteria were fewer and the pH higher Salmonella typhimurium increased to hazardous levels (Paradis and Stiles, 1978b). According to Park and Marth (1972), in addition to the production of acid by these bacteria and hence a drop in pH, inhibition is due to the production of certain compounds (hydrogen peroxide, antibiotics). In general a high lactic

acid bacteria inocula and high temperatures will suppress more Salmonella growth than low inocula and low temperatures.

4.3. Effect of atmosphere on growth

Several investigators have shown that salmonellae are able to grow on vacuum packed foods. Davidson and Webb (1973) reported that Salmonella typhimurium was able to grow on vacuum packed cooked chicken and bologna stored at 24°C, but not at 4°C.

Stiles and Ng (1979) simulated contamination of vacuum packed hams with pathogenic bacteria, including Salmonella typhimurium. After 30 days at 4 and 10°C, samples were held at 30°, 21° and 4°C under normal atmosphere to simulate sandwich handling. Incubation at the two higher temperatures resulted in the growth of Salmonella typhimurium to potentially hazardous levels. White and Hobbs (1963) found that vacuum packaging did not affect the growth of Salmonella on slices of cooked ham, luncheon meat and brawn stored at 4°, 22° and 37°C.

In contrast to these results, vacuum packing was found to produce a longer lag period and reduced magnitude of growth of Salmonella typhimurium and Salmonella anatum in sliced luncheon meats at 23°C compared with aerobic conditions of storage (Goepfert and Chung, 1970).

High levels of CO_2 have been shown to have an inhibitory effect on the growth of salmonellae in foods. Shaw and Nicol (1969) reported the growth rates of Salmonella oranienberg on silverside in an atmosphere of 100% N_2 to be half those in air. Results were similar when the silverside samples were stored at 10 or 20°C. An atmosphere of 18% O_2 and 10% CO_2 or 0.6% O_2 and 10% CO_2 produced less inhibition (30%) than the N_2 atmosphere. Again inhibition by 10% CO_2 was not enhanced by reducing the temperature from 20 to 10°C.

Silliker and Woolfe (1980) found numbers of 6 strains of salmonellae to be 10^3 greater on inoculated beef samples held in air at $10^{\circ}C$ for 10 days than on similar samples held in atmospheres containing CO_2. They concluded that CO_2 did not increase the hazard of Salmonellosis from meats.

These results were confirmed by Luiten et al., (1982) who found that numbers of Salmonella typhimurium on fresh beef loin at $10^{\circ}C$ did not change on samples stored in atmospheres of 60% CO_2 or vacuum packed, whereas numbers significantly increased on samples wrapped in oxygen permeable film. They suggested that high levels of CO_2 may exert a protective effect against the development of Salmonella in meats subjected to minor or moderate temperature abuse.

5. Miscellaneous micro-organisms associated with food bourne disease.

Yersinia enterocolitica is a psychrotrophic enterobacteriaceae that can cause acute gastro enteritis or entero colitis. It is a very diverse group of organisms, many of which are harmless saprophytes. The strains of clinical importance are the human serotypes 0:3, 0:9 and 0:8. Pathogenecity appears to be linked with a 42-megadalton plasmid (Wauters, 1981).

Toxin production by Y.enterocolitica is possible at 3 - $4^{\circ}C$ (Kapperud and Langeland, 1981; Francis et al., 1980; Olsvik and Kapperud, 1982).

Hanna et al., (1977) demonstrated large increases in Yersinia enterocolitica on raw and cooked beef and pork at $7^{\circ}C$ for 10 days. At $25^{\circ}C$ the increase in Yersinia enterocolitica counts were somewhat greater on cooked than on raw products. These differences were attributed to

differences in the physico-chemical characteristics of the meat (raw versus cooked) or differences in the level and type of naturally occurring flora.

Yersinia enterocolitica was able to grow slowly at 2°C (counts increased from 10^2 to 10^5 /g in 30 days) in vacuum packed bologna sausage with low levels of competing flora and at 5°C grew rapidly, reaching 10^6/g within two weeks (Nielsen and Zeuthen, 1984)

Listeria monocytogenes is a psychrotroph, which can act as a pathogen and there are indicators that contaminated food may play a role, but as yet foodborne listeriosis is not clearly understood (Oosterom et al., 1981). Listeria monocytogenes is widely distributed in the environment and has been isolated from various foods (Gilbert, 1985).

APPENDIX 4

THE SCORE SHEETS USED IN THE PILOT SENSORY EXPERIMENT.

1. Roast chicken

Name _____ Date_____

In front of you are four samples of chicken.
Please evaluate each sample for the quality factors listed below, by placing a vertical line across the horizontal line at the point representing your opinion.

APPEARANCE (do not remove wrapper)

Sample code

Very good — Very poor

___ _____
___ _____
___ _____
___ _____

ODOUR

Very full — Bland or lacking

___ _____
___ _____
___ _____
___ _____

JUICINESS OF CHICKEN

Very juicy — Very dry

___ _____
___ _____
___ _____
___ _____

NATURAL FLAVOUR OF CHICKEN

Very full — Bland or lacking

___ _____
___ _____
___ _____
___ _____

GENERAL ACCEPTABILITY OF PRODUCT

Very good — Very poor

___ _____
___ _____
___ _____
___ _____

COMMENTS:

2. Chicken a la King

Name _____ **Date**_____

In front of you are four samples of chicken a la king.

Please evaluate each sample for its appearance, by placing a vertical line across the horizontal line at the point representing your opinion.

Then return the samples to be reheated before evaluating the other quality factors in the same manner.

APPEARANCE (do not remove wrapper)

Sample code	Very good	Very poor
____	_____	
____	_____	
____	_____	
____	_____	

RETURN SAMPLES TO BE REHEATED

ODOUR (remove wrapper)

	Very full	Bland or lacking
____	_____	
____	_____	
____	_____	
____	_____	

JUICINESS OF CHICKEN

	Very juicy	Very dry
____	_____	
____	_____	
____	_____	
____	_____	

NATURAL FLAVOUR OF CHICKEN

	Very full	Bland or lacking
____	_____	
____	_____	
____	_____	
____	_____	

GENERAL ACCEPTABILITY OF PRODUCT

	Very good	Very poor
____	_____	
____	_____	
____	_____	
____	_____	

COMMENTS:

APPENDIX 5

THE SCORE SHEETS USED IN THE MAJOR SENSORY EXPERIMENT.

1. Chicken drumsticks

Name _____ Date_____

In front of you are _____ samples of chicken drumsticks.

Please evaluate each sample for the quality factors listed below, by placing a vertical line across the horizontal line at the point representing your opinion.

APPEARANCE

Shrivelled

Sample code

No shrivelling — Very shrivelled

____	____
____	____
____	____
____	____
____	____

Brightness

Not bright — Very bright

____	____
____	____
____	____
____	____
____	____

Dry appearance of flesh

Not dry — Very dry

____	____
____	____
____	____
____	____
____	____

Compact appearance of flesh

Moderately compact — Very compact

____	____
____	____
____	____
____	____
____	____

ODOUR

Natural fried chicken odour

Sample code

Weak Strong

Rancid odour

Absent Strong

Bland odour

Weak Strong

TEXTURE

Juiciness of flesh

Sample code

Not juicy Very juicy

Degree of chewing

Low High

First bite

Less resistant More resistant

FLAVOUR

Fresh fried chicken flavour

Sample code

Weak Strong

Rancid flavour

Weak Strong

Bland flavour

Weak Strong

Additional comments

2. Chicken a la king

Name _____ **Date**_____

In front of you are ___ samples of chicken a la king.

Please evaluate each sample for the quality factors listed below, by placing a vertical line across the horizontal line at the point representing your opinion.

APPEARANCE

Sauce:

Granular/pastey

Sample code

Absent Present

___ _____
___ _____
___ _____
___ _____
___ _____

Gelatinous texture

Not set Well set

___ _____
___ _____
___ _____
___ _____
___ _____

Depth of colour

Weak Full

___ _____
___ _____
___ _____
___ _____
___ _____

Sauces coating properties (peas/pimentos)

No coating Coats well

___ _____
___ _____
___ _____
___ _____
___ _____

Appearance of meat

Broken up — Whole

Shade of pea colour

Fresh pea colour — olive — khaki

Pea colour range

Not variable — Variable

Return samples for reheating

Surface oil on reheated sample

Absent — Present

ODOUR

Sauce odour

Fresh — Stale

Depth of chicken odour

Weak — Strong

TEXTURE

Sauce texture

Coarse — Smooth

Meat texture

Breaks down readily — Chewy

Variability of pea texture

Not variable (same texture throughout) — Variable (soft centred)

FLAVOUR

Staleness

Absent — Present

Acidic flavour

Absent — Present

Degree of sweetness

Weak Strong

Degree of saltiness

Weak Strong

Chicken flavour of meat

Bland Full

Comments:

F VALUES FOR INDIVIDUALS FOR ONE WAY ANALYSIS OF VARIANCE OF SENSORY ATTRIBUTE SCORES OF CHICKEN DRUMSTICKS

Key of sensory attributes

1. Shrivelled
2. Brightness
3. Dry appearance of flesh
4. Compact appearance of flesh
5. Fried chicken odour
6. Rancid odour
7. Bland odour
8. Juiciness of flesh
9. Degree of chewing
10. First bite
11. Fried chicken odour
12. Rancid flavour
13. Bland flavour

One way ANOVA by replication.

	Sensory attributes (see key)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Subject													
Vacuum													
1.	0.63	1.74	0.30	0.37	0.72	4.04	1.14	7.16	2.58	0.99	1.22	0.71	3.35
2.	1.36	0.13	0.14	0.22	0.43	1.46	0.40	0.13	0.25	0.18	1.66	2.35	0.11
3.	0.59	0.21	1.58	1.01	1.40	0.97	0.63	0.55	0.51	0.24	1.03	3.33	1.68
4.	3.57	0.96	0.81	0.42	0.31	2.63	0.54	1.67	1.80	0.065	0.26	1.78	4.13
5.	2.45	1.69	0.40	8.10	4.30	6.91	0.74	0.92	6.51	3.64	5.84	2.66	7.20
6.	0.34	0.42	0.28	0.23	0.41	2.66	0.71	0.09	0.41	0.29	1.43	2.06	1.86
7.	0.53	0.52	1.04	0.31	0.07	0.51	0.10	1.02	0.62	0.04	0.65	0.48	1.19
8.	1.74	2.00	0.99	1.15	0.13	1.01	0.13	0.48	0.32	0.31	2.41	0.69	0.57
MAP													
1.	1.78	0.17	0.49	1.94	1.13	2.93	1.95	1.05	3.3	0.47	1.77	0.29	2.17
2.	1.01	0.13	0.53	0.04	0.26	0.17	0.49	0.36	0.45	0.32	0.79	0.36	0.44
3.	0.44	4.88	1.58	2.02	0.69	5.03	10.15	3.90	2.65	0.57	0.66	8.38	3.63
4.	2.65	3.14	0.13	0.89	1.12	0.91	0.55	0.78	0.89	0.35	0.36	0.70	1.27
5.	4.91	2.61	2.15	1.67	0.96	2.43	0.75	3.39	2.51	4.21	2.45	0.83	5.56
6.	0.33	0.04	0.11	1.26	1.17	0.70	0.49	0.50	0.49	0.22	0.91	0.57	1.83
7.	1.78	0.54	1.42	0.23	1.45	0.67	1.36	0.77	0.42	0.24	0.48	0.95	0.27
8.	0.88	1.61	3.10	0.72	1.58	0,.74	0.15	0.98	0.40	1.14	0.55	1.05	2.19
Cling wrapping													
1.	0.70	0.61	4.04	0.27	1.34	0.91	0.70	3.73	2.02	0.46	2.48	1.12	3.07
2.	0.36	0.05	0.30	0.16	0.49	1.22	0.48	0.14	0.64	0.29	1.46	0.55	1.94
3.	2.23	0.43	1.60	0.66	0.43	1.38	0.21	0.30	0.12	0.14	0.65	4.59	2.77
4.	0.32	1.04	0.35	0.76	0.10	1.59	0.31	0.72	1.4	0.09	0.69	126	2.32
5.	2.57	5.20	0.57	3.78	2.09	2.69	0.32	0.35	0.7	1.51	1.07	0.92	0.63
6.	1.19	1.63	1.54	1.17	0.74	1.21	0.17	0.91	1.37	0.18	1.02	0.87	0.49
7.	0.19	0.28	0.38	0.18	0.06	0.58	0.04	0.35	0.11	0.39	0.49	1.45	0.82

One way ANOVA by storage life

Sensory attributes (see key)

	1	2	3	4	5	6	7	8	9	10	11	12	13
Subject													
Vacuum													
1.	1.03	0.43	1.87	1.83	6.46	4.04	2.4	0.13	1.62	3.69	0.86	2.66	1.16
2.	1.19	4.80	8.1	10.19	18.95	1.4	13.86	2.61	7.06	33.84	3.66	5.09	7.27
3.	3.18	0.99	3.64	1.96	2.89	0.97	2.73	4.96	8.42	16.01	4.49	1.66	1.84
4.	1.8	4.84	6.63	5.78	22.03	2.63	14.61	4.15	4.21	63.2	5.51	8.14	2.82
5.	0.56	0.72	9.89	1.27	1.19	6.91	4.68	6.5	1.8	0.88	0.83	0.97	1.01
6.	5.29	2.56	3.08	3.00	2.82	2.66	7.77	4.52	5.00	19.21	1.23	1.64	71.65
7.	3.74	13.72	5.5	6.32	33.62	1.87	29.1	1.6	6.26	73.75	2.42	0.88	2.86
8.	1.93	1.07	2.2	2.18	12.06	6.47	12.96	12.21	11.61	8.48	2.49	1.75	1.30
	MAP												
1.	0.61	2.94	4.93	0.87	4.86	3.61	2.43	1.17	0.73	6.53	3.9	3.92	2.25
2.	1.52	1.43	3.98	2.89	15.19	16.47	4.33	1.05	1.12	13.31	2.65	4.42	6.93
3.	1.92	1.45	1.0	0.27	9.53	0.99	0.51	0.69	1.66	7.12	3.79	1.69	2.65
4.	0.43	0.63	6.46	5.97	4.77	6.54	7.89	7.53	5.65	15.42	4.14	2.52	0.86
5.	1.40	1.61	1.80	1.14	5.28	3.07	2.35	1.74	1.75	2.72	4.20	2.05	0.64
6.	1.89	10.11	2.39	0.47	8.44	0.45	12.48	10.98	5.22	16.29	1.61	2.61	1.45
7.	0.69	8.21	2.44	3.55	3.93	4.67	6.20	2.74	2.73	11.94	6.06	1.06	2.07
8.	0.63	1.86	1.03	1.40	3.21	3.42	6.06	5.51	5.81	2.29	2.62	3.78	0.31
	Cling wrapping												
1.	1.27	1.40	0.83	0.65	7.56	11.44	2.36	0.51	1.68	8.21	1.86	2.34	1.84
2.	14.20	3.65	4.2	5.32	17.34	4.77	12.29	9.42	14.5	31.34	3.63	5.99	3.92
3.	1.8	1.96	3.17	5.00	18.74	3.86	11.6	10.64	20.06	25.39	9.0	1.93	3.27
4.	4.16	2.84	8.16	5.45	15.0	2.76	21.96	11.21	4.91	54.68	10.45	3.19	1.05
5.	1.62	0.74	8.33	1.38	4.21	1.51	10.12	3.98	5.79	6.25	5.98	2.90	3.65
6.	3.17	0.51	3.29	3.27	2.15	3.61	8.57	2.47	3.47	7.49	4.74	0.61	1.59
7.	11.53	3.07	4.33	6.82	47.66	9.62	60.58	0.76	5.76	10.42	5.81	0.96	0.97
8.	0.63	8.72	1.72	6.61	23.19	6.54	15.31	15.24	9.95	45.74	6.39	9.17	5.75

APPENDIX 7

F VALUES FOR INDIVIDUALS FOR ONE WAY ANALYSIS OF VARIANCE OF SENSORY ATTRIBUTE SCORES OF CHICKEN A LA KING

Key of sensory attributes

1. Granular/pastey
2. Gelatinous texture
3. Depth of colour
4. Sauces coating properties
5. Appearance of meat
6. Shade of pea colour
7. Pea colour range
8. Surface oil on reheated sample
9. Sauce odour
10. Depth of chicken odour
11. Sauce texture
12. Meat texture
13. Variability of pea texture
14. Staleness
15. Acidic flavour
16. Degree of sweetness
17. Degree of saltiness
18. Chicken flavour of meat

One way ANOVA by storage life.

Sensory attributes(see key)

	1	2	3	4	5	6	7	8	9
Subject									
Vacuum									
1.	0.38	0.70	3.58	1.58	1.69	2.34	0.27	1.46	0.74
2.	2.70	5.67d	4.93d	8.87d	2.30	2.82	5.08	2.06	1.41
3.	4.20d	2.31	3.33d	4.53d	1.01	1.52	2.04	1.00	0.23
4.	1.67	2.38	1.31	3.5d	2.51	3.17	1.05	0.53	2.09
5.	7.97d	0.68	12.35d	9.07d	3.05d	2.96d	0.32	2.45	0.81
MAP									
1.	1.05	2.15	2.56	1.33	0.40	6.80d	1.81	1.53	0.88
2.	1.86	2.36	2.29	10.71d	1.87	9.06d	1.07	0.51	0.18
3.	5.03d	2.26	2.48	3.32d	1.84	18.42d	7.87d	0.11	1.63
4.	4.48d	3.73d	2.14	1.32	3.12d	4.44d	4.41d	0.33	1.36
5.	1.53	1.83	2.79	2.42	3.56d	9.01d	1.26	0.53	2.71
Cling wrapping									
1.	0.00	6.61d	3.76d	2.23	4.,44d	0.40	0.24	0.30	1.34
2.	4.98d	0.10	4.90d	0.80	1.46	8.33d	0.38	2.64	1.58
3.	3.72d	1.89	5.27d	2.28	0.78	4.95d	7.63d	1.22	1.76
4.	1.04	0.98	0.16	5.61d	3.66	0.16	0.35	1.18	0.13
5.	9.16d	0.78	8.53d	2.73	1.63	1.36	0.50	2.86	0.26

Sensory attributes (see key)

	10	11	12	13	14	15	16	17	18
Subject									
Vacuum									
1.	0.51	0.32	0.61	2.84	0.21	0.72	0.27	0.14	0.18
2.	1.25	2.41	0.11	0.69	0.80	0.33	1.83	0.40	0.57
3.	2.05	0.28	0.13	0.42	0.39	0.84	1.31	2.35	0.67
4.	1.16	2.42	1.92	0.45	1.33	0.23	0.16	0.51	1.64
5.	0.58	6.00d	0.51	0.35	0.84	0.56	0.40	0.22	0.41
MAP									
1.	2.16	0.19	0.20	2.18	2.59	1.16	0.53	0.17	0.19
2.	0.51	0.31	0.56	1.06	0.44	1.20	0.25	0.39	0.81
3.	1.30	1.64	0.52	1.49	0.86	0.35	1.37	0.89	0.51
4.	1.70	2.09	2.02	0.79	1.21	0.23	2.02	0.29	4.15d
5.	0.26	1.89	3.68d	2.08	1.06	0.37	0.96	0.19	1.64
Cling wrapping									
1.	4.80d	0.57	0.61	0.83	0.62	0.72	0.17	0.51	0.39
2.	1.19	1.04	1.21	0.84	2.61	0.99	0.57	4.00d	1.39
3.	1.71	0.61	0.51	1.38	1.11	0.19	1.87	0.71	3.87d
4.	0.27	0.36	1.57	0.06	0.08	0.47	0.49	0.008	0.05
5.	0.25	0.31	0.02	1.46	0.17	0.53	0.47	0.43	0.32

One way ANOVA by replication

Sensory attributes (see key)

Subject	1	2	3	4	5	6	7	8	9
Vacuum									
1.	2.08	1.52	0.55	2.55	1.10	1.06	1.74	0.30	3.02d
2.	2.17	0.04	1.43	0.25	0.57	2.86	1.20	0.23	0.39
3.	0.18	2.03	2.36	0.59	0.86	0.30	0.17	0.57	1.58
4.	0.15	0.42	2.57	0.27	0.68	0.70	2.07	0.92	2.11
5.	0.60	0.44	0.10	0.16	1.19	1.15	3.09d	0.81	1.61
MAP									
1.	0.22	1.14	2.04	2.10	1.25	0.77	2.59	0.46	1.31
2.	3.91d	0.73	3.03d	0.58	0.93	0.73	3.02d	0.54	2.74
3.	1.86	0.92	3.53d	0.64	1.12	0.39	0.19	0.12	1.53
4.	0.27	0.97	0.75	1.14	0.28	1.42	0.56	0.49	3.97d
5.	3.51d	0.67	0.88	0.93	0.65	0.26	1.29	0.47	0.95
Cling wrapping									
1.	0.92	0.48	0.44	0.48	0.34	0.46	2.18	2.40	1.20
2.	0.20	4.34d	1.97	1.09	1.15	0.21	3.33d	0.88	2.72
3.	0.63	0.82	0.70	0.83	2.23	0.18	0.10	2.06	1.44
4.	1.09	0.76	2.51	0.39	0.49	0.43	2.98	2.78	2.92
5.	0.72	0.21	0.27	0.15	2.23	1.74	1.74	0.37	1.96

Sensory attributes (see key)

Subject	10	11	12	13	14	15	16	17	18
Vacuum									
1.	0.43	2.00	8.26d	0.72	1.46	2.65	1.18	3.69	2.58
2.	0.87	1.96	0.86	1.93	2.01	0.92	0.56	1.40	3.38
3.	0.69	2.53	0.93	1.76	1.30	0.59	2.71	0,60	0.61
4.	2.96d	0.81	1.49	3.56d	0.87	4.84d	4.64d	0.57	2.95
5.	0.88	0.06	0.74	6.95d	2.95d	6.29d	3.04d	11.23d	1.63
MAP									
1.	0.27	2.91d	0.43	0.59	1.50	5.24d	2.02	1.87	5.98d
2.	0.58	1.22	2.44	1.40	3.37	2.11	1.18	1.11	5.30d
3.	1.38	0.41	0.28	1.22	1.27	0.84	0.30	3.34	0.75
4.	1,63	2.57	0.91	0.27	1.92	10.09d	1.25	1.04	0.55
5.	0.28	1.37	0.44	0.87	1.46	2.55	1.75	14.03d	2.27
Cling wrapping									
1.	0.45	4.27d	3.47d	0.48	0.74	4.29d	7.11d	2.01	1.74
2.	3.17	3.41	1.31	2.02	3.50d	2.98	1.98	0.56	3.36
3.	1.23	0.78	6.29	0.07	0.75	1.72	1.23	0.49	0.32
4.	0.35	4.79d	1.26	1.59	1.27	7.15d	0.67	2.55	6.51d
5.	0.26	0.12	3.06	0.67	0.59	1.07	3.14	5.67d	2.63

APPENDIX 8

SUMMARY TABLES FOR THE ANALYSIS OF VARIANCE OF CHICKEN DRUMSTICKS

Key: The attribute descriptive terms of chicken drumsticks

APPEARANCE			
D1	Shrivelled	No shrivelling	Very shrivelled
D2	Brightness	Not bright	Very bright
D3	Dry appearance of flesh	Not Dry	Very dry
D4	Compact appearance of flesh	Moderately compact	Very compact
ODOUR			
D5	Natural fried chicken odour	Weak	Strong
D6	Rancid odour	Absent	Strong
D7	Bland odour	Weak	Strong
TEXTURE			
D8	Juiciness of flesh	Not juicy	Very juicy
D9	Degree of chewing	Low	High
D10	First bite	Less resistant	More resistant
FLAVOUR			
D11	Fresh fried chicken flavour	Weak	Strong
D12	Rancid flavour	Weak	Strong
D13	Bland flavour	Weak	Strong

MODEL ONE; 3 levels of packaging and 5 levels of age.

TESTS OF SIGNIFICANCE FOR D1 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	30.01	4	7.50	2.37	
PACK	73.29	2	36.64	11.59	P<0.01
PACK BY REPN	25.34	8	3.16		
TOTAL	128.64				
AGE	74.60	2	37.30	9.71	P<0.01
REPN BY AGE	64.89	8	8.11	2.11	
PACK BY AGE	58.76	4	14.69	3.82	P<0.025
REPN BY PACK BY AGE	61.40	16	3.84		
TOTAL	259.65				
TASTER	286.42	7	40.92	2.41	P<0.025
REPN BY TASTER	111.55	28	3.98	0.01	
PACK BY TASTER	58.76	14	4.20	0.25	
AGE BY TASTER	390.03	14	27.86	1.64	
ERROR (C)	4292.73	253	16.97		
TOTAL	5139.49				
GRAND TOTAL	5527.78	360			

TESTS OF SIGNIFICANCE FOR D2 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	46.39	4	11.60	2.25	
PACK	15.93	2	7.96	1.54	
PACK BY REPN	41.31	8	5.16		
TOTAL	103.64	14			
AGE	278.07	2	139.03	27.10	P<0.001
REPN BY AGE	138.43	8	17.30	3.37	P<0.025
PACK BY AGE	33.70	4	8.42	1.64	
REPN BY PACK BY AGE	82.17	16	5.13		
TOTAL	523.39	30			
TASTER	310.58	7	44.36	2.01	
REPN BY TASTER	109.94	28	3.93	0.18	
PACK BY TASTER	18.76	14	1.34	0.06	
AGE BY TASTER	511.98	14	36.57	1.65	
ERROR (C)	5594.43	253	22.11		
TOTAL	6536.69				
GRAND TOTAL	7172.72	360			

TESTS OF SIGNIFICANCE FOR D3 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	23.45	4	5.86	5.80	P<0.025
PACK	.85	2	.42	0.42	
PACK BY REPN	8.14	8	1.01		
TOTAL	32.45	14			
AGE	503.20	2	251.60	66.91	P<0.001
REPN BY AGE	79.09	8	9.89	2.63	P<0.05
PACK BY AGE	21.36	4	5.34	1.42	
REPN BY PACK BY AGE	60.22	16	3.76		
TOTAL	663.88	30			
TASTER	79.49	7	11.35	0.63	
REPN BY TASTER	81.34	28	2.90	0.16	
PACK BY TASTER	45.08	14	3.22	0.18	
AGE BY TASTER	143.53	14	10.25	0.57	
ERROR (C)	4553.2	253	18.00		
TOTAL	4902.6				
GRAND TOTAL	5598.97	360			

TESTS OF SIGNIFICANCE FOR D4 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	8.50	4	2.12	1.04	
PACK	7.76	2	3.88	1.90	
PACK BY REPN	16.35	8	2.04		
TOTAL	32.63	14			
AGE	323.10	2	161.55	47.37	
REPN BY AGE	61.92	8	7.74	2.27	
PACK BY AGE	19.89	4	4.97	1.46	
REPN BY PACK BY AGE	54.63	16	3.41		
TOTAL	494.54	30			
TASTER	132.68	7	18.95	0.96	
REPN BY TASTER	98.53	28	3.52	0.18	
PACK BY TASTER	10.53	14	.75	0.04	
AGE BY TASTER	238.78	14	17.05	0.86	
ERROR (C)	4982.96	253	19.69		
TOTAL	5463.48				
GRAND TOTAL	5955.	360			

TESTS OF SIGNIFICANCE FOR D5 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	9.98	4	2.49	0.44	
PACK	23.19	2	11.59	2.05	
PACK BY REPN	45.24	8	5.65		
TOTAL	27.40	14			
AGE	1207.22	2	603.61	150.05	P<0.001
REPN BY AGE	56.62	8	7.08	1.76	
PACK BY AGE	51.21	4	12.80	3.18	
REPN BY PACK BY AGE	64.33	16	4.02		
TOTAL	1379.38	30			
TASTER	101.78	7	14.54	0.81	
REPN BY TASTER	175.69	28	6.27	0.35	
PACK BY TASTER	27.90	14	1.99	0.11	
AGE BY TASTER	218.18	14	15.58	0.87	
ERROR (C)	4550.00	253	17.98		
TOTAL	5073.55				
GRAND TOTAL	6480.33	360			

TESTS OF SIGNIFICANCE FOR D6 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	41.45	4	10.36	1.06	
PACK	197.52	2	98.76	10.09	P<0.01
PACK BY REPN	78.35	8	9.79		
TOTAL	317.33	14			
AGE	430.53	2	215.26	25.38	P<0.001
REPN BY AGE	67.09	8	8.39	0.99	
PACK BY AGE	275.95	4	68.99	8.13	P<0.001
REPN BY PACK BY AGE	135.66	16	8.48		
TOTAL	909.25	30			
TASTER	76.78	7	10.96	1.22	
REPN BY TASTER	109.58	28	3.91	0.45	
PACK BY TASTER	101.75	14	7.27	0.84	
AGE BY TASTER	123.28	14	8.81	1.02	
ERROR (C)	2193.59	253	8.67		
TOTAL	2604.98				
GRAND TOTAL	3831.56	360			

TESTS OF SIGNIFICANCE FOR D7 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	38.76	4	9.69	3.99	P<0.05
PACK	34.96	2	17.48	7.19	P<0.025
PACK BY REPN	19.47	8	2.43		
TOTAL	93.20	14			
AGE	992.02	2	496.01	99.00	P<0.001
REPN BY AGE	52.77	8	6.60	1.32	
PACK BY AGE	74.89	4	18.72	3.74	P<0.025
REPN BY PACK BY AGE	80.25	16	5.01		
TOTAL	1199.95	30			
TASTER	161.07	7	23.01	1.15	
REPN BY TASTER	59.76	28	2.13	0.11	
PACK BY TASTER	32.39	14	2.31	0.12	
AGE BY TASTER	287.65	14	20.55	1.03	
ERROR (C)	5054.43	253	19.98		
TOTAL	5595.30				
GRAND TOTAL	6888.45	360			

TESTS OF SIGNIFICANCE FOR D8 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	34.42	4	8.60	2.95	
PACK	29.38	2	14.69	5.05	
PACK BY REPN	23.30	8	2.91		
TOTAL	87.11	14			
AGE	468.08	2	234.04	58.66	P<0.001
PACK BY AGE	73.14	8	9.14	2.29	
PACK BY AGE	46.20	4	11.55	2.89	
REPN BY PACK BY AGE	63.83	16	3.99		
TOTAL	651.26	30			
TASTER	150.45	7	21.49	1.07	
REPN BY TASTER	81.74	28	2.92	0.14	
PACK BY TASTER	34.65	14	2.47	0.12	
AGE BY TASTER	243.96	14	17.42	0.87	
ERROR (C)	5068.29	253	20.03		
TOTAL	5579.10	14			
GRAND TOTAL	6317.47	360			

TESTS OF SIGNIFICANCE FOR D9 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	56.90	4	14.22	7.52	P<0.01
PACK	26.20	2	13.10	6.93	P<0.025
PACK BY REPN	15.18	8	1.89		
TOTAL	98.29	14			
AGE	590.08	2	295.04	112.61	P<0.001
REPN BY AGE	93.36	8	11.67	4.45	P<0.01
PACK BY AGE	61.30	4	15.32	5.85	P<0.01
REPN BY PACK BY AGE	41.93	16	2.62		
TOTAL	786.68	30			
TASTER	193.87	7	27.69	1.61	
REPN BY TASTER	75.33	28	2.69	0.16	
PACK BY TASTER	33.45	14	2.39	0.14	
AGE BY TASTER	272.90	14	19.49	1.13	
ERROR (C)	4354.15	253	17.21		
TOTAL	4929.71				
GRAND TOTAL	5814.68	360			

TESTS OF SIGNIFICANCE FOR D10 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	17.54	4	4.38	1.70	
PACK	6.07	2	3.03	1.18	
PACK BY REPN	20.57	8	2.57		
TOTAL	44.2	14			
AGE	1334.28	2	667.14	230.05	P<0.001
REPN BY AGE	34.22	8	4.28	1.47	
PACK BY AGE	13.79	4	2.45	0.84	
REPN BY PACK BY AGE	46.45	16	2.90		
TOTAL	1428.74	30			
TASTER	66.74	7	9.53	0.64	
REPN BY TASTER	100.87	28	3.60	0.24	
PACK BY TASTER	43.33	14	3.09	0.21	
AGE BY TASTER	202.84	14	14.49	0.97	
ERROR (C)	3763.57	253	14.87		
TOTAL	4177.35				
GRAND TOTAL	5650.29	360			

TESTS OF SIGNIFICANCE FOR D11 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	55.37	4	13.84	2.52	
PACK	139.79	2	69.89	12.73	
PACK BY REPN	43.94	8	5.49		
TOTAL	242.11	14			
AGE	305.97	2	152.98	25.93	P<0.01
REPN BY AGE	74.63	8	9.33	1.58	
PACK BY AGE	244.52	4	61.13	10.36	P<0.001
REPN BY PACK BY AGE	95.78	16	5.9		
TOTAL	720.90				
TASTER	193.85	7	27.69	4.09	P<0.001
REPN BY TASTER	99.17	28	3.54	0.52	
PACK BY TASTER	103.21	14	7.37	1.09	
AGE BY TASTER	257.70	14	18.40	2.71	P<0.01
ERROR (C)	1716.42	253	6.78		
TOTAL	2370.35				
GRAND TOTAL	3333.36	360			

TESTS OF SIGNIFICANCE FOR D12 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	4.07	4	1.02	0.20	
PACK	50.93	2	25.46	5.06	P<0.05
PACK BY REPN	40.31	8	5.03		
TOTAL	95.32	14			
AGE	592.10	2	296.05	58.86	P<0.001
REPN BY AGE	25.76	8	3.22	0.64	
PACK BY AGE	74.32	4	18.58	3.69	P<0.05
REPN BY PACK BY AGE	80.44	16	5.03		
TOTAL	772.62	30			
TASTER	290.40	7	41.48	2.81	P<0.01
REPN BY TASTER	189.80	28	6.78	0.46	
PACK BY TASTER	82.00	14	5.86	0.40	
AGE BY TASTER	419.67	14	29.98	2.03	
ERROR (C)	3733.09	253	14.75		
TOTAL	4714.97				
GRAND TOTAL	5582.91	360			

TESTS OF SIGNIFICANCE FOR D13 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	19.90	4	4.97	1.30	
PACK	40.85	2	20.42	5.34	P<0.001
PACK BY REPN	30.61	8	3.82		
TOTAL	91.37	14			
AGE	437.66	2	218.83	35.18	P<0.001
REPN BY AGE	60.83	8	7.60	1.22	
PACK BY AGE	64.01	4	16.00	2.57	
REPN BY PACK BY AGE	99.57	16	6.22		
TOTAL	662.07				
TASTER	225.66	7	32.23	2.38	P<0.025
REPN BY TASTER	167.31	28	5.97	0.44	
PACK BY TASTER	84.47	14	5.96	0.44	
AGE BY TASTER	318.53	14	22.75	1.68	
ERROR (C)	3425.47	253	13.54		
TOTAL	4221.45				
GRAND TOTAL	4974.89	360			

Model two; 2 levels of packaging and 5 levels of age.

TESTS OF SIGNIFICANCE FOR D1 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	7.45	4	1.86	0.85	
PACK	94.57	1	94.57	43.38	P<0.01
PACK BY REPN	8.75	4	2.18		
TOTAL	110.77	9			
AGE	28.64	4	7.16	2.37	
REPN BY AGE	66.50	16	4.16	1.38	
AGE BY PACK	39.36	4	9.84	3.26	P<0.05
REP BY AGE BY PACK	48.21	16	3.01		
TOTAL	182.71	40			
TASTER	251.94	7	35.99	2.07	P<0.05
PACK BY TASTER	96.98	7	13.85	0.80	
AGE BY TASTER	189.68	28	6.77	0.39	
REPN BY TASTER	183.28	28	6.54	0.38	
ERROR C	4868.46	280	17.39		
TOTAL	5883.82	399			

TESTS OF SIGNIFICANCE FOR D2 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	26.37	4	6.58	2.19	
PACK	26.99	1	26.99	8.97	P<0.05
PACK BY REPN	12.03	4	3.01		
TOTAL	65.39	9			
AGE	286.74	4	71.68	36.57	P<0.01
REPN BY AGE	119.62	16	7.47	3.81	P<0.01
AGE BY PACK	15.38	4	3.84	1.96	
REP BY AGE BY PACK	31.33	16	1.96		
TOTAL	453.07	40			
TASTER	242.81	7	34.69	1.77	
PACK BY TASTER	29.77	7	4.25	0.22	
AGE BY TASTER	231.04	28	8.25	0.42	
REPN BY TASTER	158.25	28	5.65	0.29	
ERROR C	5478.47	280	19.56		
TOTAL	6658.8	399			

TESTS OF SIGNIFICANCE FOR D3 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	26.68	4	6.67	1.43	
PACK	1.02	1	1.02	0.22	
PACK BY REPN	18.67	4	4.66		
TOTAL	46.37	9			
AGE	510.50	4	127.63	34.68	P<0.01
REPN BY AGE	64.81	16	4.05	1.10	
AGE BY PACK	19.32	4	4.83	1.31	
REP BY AGE BY PACK	58.83	16	3.68		
TOTAL	653.46	40			
TASTER	93.16	7	13.31	0.54	
PACK BY TASTER	50.39	7	7.20	0.29	
AGE BY TASTER	139.16	28	4.99	0.20	
REPN BY TASTER	121.52	28	4.34	0.17	
ERROR C	6832.61	280	24.40		
TOTAL	7936.68	399			

TESTS OF SIGNIFICANCE FOR D4 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	8.40	4	2.10	0.28	
PACK	22.37	1	22.37	3.02	
PACK BY REPN	29.64	4	7.41		
TOTAL	60.4	9			
AGE	340.10	4	85.03	36.49	P<0.01
REPN BY AGE	65.65	16	4.1	1.76	
AGE BY PACK	13.45	4	3.36	1.44	
REP BY AGE BY PACK	37.33	16	2.33		
TOTAL	456.53	40			
TASTER	163.60	7	23.37	0.92	
PACK BY TASTER	6.93	7	.99	0.04	
AGE BY TASTER	140.11	28	5.15	0.20	
REPN BY TASTER	103.89	28	3.71	0.15	
ERROR C	7097.45	280	25.35		
TOTAL	8028.92				

TESTS OF SIGNIFICANCE FOR D5 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	1.83	4	.46	0.05	
PACK	11.97	1	11.97	1.21	
PACK BY REPN	39.57	4	9.89		
TOTAL	53.37	9			
AGE	1086.77	4	271.69	249.26	P<0.01
REPN BY AGE	50.26	16	3.14	2.88	P<0.05
AGE BY PACK	8.32	4	2.08	1.90	
REP BY AGE BY PACK	17.49	16	1.09		
TOTAL	1162.84	40			
TASTER	234.88	7	33.55	2.75	P<0.01
PACK BY TASTER	14.84	7	2.12	0.17	
AGE BY TASTER	133.7	28	4.8	0.39	
REPN BY TASTER	177.05	28	6.32	0.52	
ERROR C	3419.02	280	12.21		
TOTAL	5195.75	399			

TESTS OF SIGNIFICANCE FOR D6 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	37.61	4	9.40	0.48	
PACK	14.25	1	14.25	0.73	
PACK BY REPN	78.19	4	19.55		
TOTAL	130.05	9			
AGE	671.51	4	167.88	30.30	P<0.01
REPN BY AGE	57.02	16	3.56	0.64	
AGE BY PACK	26.13	4	6.53	1.18	
REP BY AGE BY PACK	88.74	16	5.54		
TOTAL	843.40	40			
TASTER	266.89	7	38.13	2.84	P<0.01
PACK BY TASTER	35.34	7	5.04	0.37	
AGE BY TASTER	219.8	28	7.8	0.58	
REPN BY TASTER	212.95	28	7.6	0.57	
ERROR C	3755.07	280	13.41		
TOTAL	5463.5	399			

TESTS OF SIGNIFICANCE FOR D7 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	30.43	4	7.61	2.30	
PACK	41.93	1	41.93	12.67	P<0.05
PACK BY REPN	13.22	4	3.31		
TOTAL	85.58	9			
AGE	857.66	4	214.41	72.93	P<0.05
REPN BY AGE	41.00	16	2.56	0.87	
AGE BY PACK	27.96	4	6.99	2.38	
REP BY AGE BY PACK	47.07	16	2.94		
TOTAL	973.69	40			
TASTER	167.70	7	23.96	1.59	
PACK BY TASTER	16.21	7	2.32	6.49	P<0.01
AGE BY TASTER	142.82	28	5.1	0.34	
REPN BY TASTER	101.71	28	3.63	0.24	
ERROR C	4217.81	280	15.06		
TOTAL	5705.52	399			

TESTS OF SIGNIFICANCE FOR D8 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	39.08	4	9.77	1.07	
PACK	18.53	1	18.53	2.04	
PACK BY REPN	36.36	4	9.09		
TOTAL	93.97	9			
AGE	512.89	4	128.22	79.15	P<0.01
REPN BY AGE	109.42	16	6.83	4.22	P<0.05
AGE BY PACK	10.68	4	2.67	1.65	
REP BY AGE BY PACK	25.9	16	1.62		
TOTAL	658.89	40			
TASTER	264.96	7	37.85	1.49	
PACK BY TASTER	19.47	7	2.78	0.11	
AGE BY TASTER	160.51	28	5.73	0.22	
REPN BY TASTER	149.12	28	5.32	0.21	
ERROR C	7119.63	280	25.43		
TOTAL	8466.56	399			

TESTS OF SIGNIFICANCE FOR D9 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	15.48	4	3.87	0.61	
PACK	19.94	1	19.94	3.14	
PACK BY REPN	25.35	4	6.34		
TOTAL	60.77	9			
AGE	603.17	4	150.79	24.16	P<0.01
REPN BY AGE	104.79	16	6.55	1.05	
AGE BY PACK	29.38	4	7.35	1.18	
REP BY AGE BY PACK	99.9	16	6.24		
TOTAL	837.24	40			
TASTER	341.45	7	48.78	2.17	
PACK BY TASTER	41.75	7	5.96	0.26	
AGE BY TASTER	170.19	28	6.07	0.27	
REPN BY TASTER	162.74	28	5.81	0.26	
ERROR C	6287.62	280	22.45		
TOTAL	7901.77	399			

TESTS OF SIGNIFICANCE FOR D10 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	5.10	4	1.27	0.58	
PACK	.14	1	.14	0.06	
PACK BY REPN	8.73	4	2.18		
TOTAL	13.97	9			
AGE	1189.43	4	297.36	207.94	P<0.01
REPN BY AGE	28.93	16	1.81	1.26	
AGE BY PACK	5.11	4	1.28	0.89	
REP BY AGE BY PACK	22.85	16	1.43		
TOTAL	1246.32	40			
TASTER	142.39	7	20.34	2.48	P<0.05
PACK BY TASTER	4.61	7	.66	0.07	
AGE BY TASTER	157.2	28	5.61	0.59	
REPN BY TASTER	75.87	28	2.71	0.29	
ERROR C	2650.74	280	9.47		
TOTAL	4292.12	399			

TESTS OF SIGNIFICANCE FOR D11 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	71.48	4	17.87	1.56	
PACK	57.46	1	57.46	5.01	
PACK BY REPN	45.86	4	11.47		
TOTAL	174.8	9			
AGE	464.03	4	116.01	22.01	P<0.01
REPN BY AGE	31.13	16	1.94	0.37	
AGE BY PACK	22.97	4	5.74	1.09	
REP BY AGE BY PACK	84.4	16	5.27		
TOTAL	602.53	40			
TASTER	457.31	7	65.33	5.83	P<0.01
PACK BY TASTER	22.79	7	3.25	0.29	
AGE BY TASTER	171.75	28	6.13	0.55	
REPN BY TASTER	154.70	28	5.52	0.49	
ERROR C	3138.05	280	11.21		
TOTAL	4721.94	399			

TESTS OF SIGNIFICANCE FOR D12 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	9.14	4	2.28	0.39	
PACK	3.19	1	3.19	0.56	
PACK BY REPN	22.88	4	5.72		
TOTAL	35.13	9			
AGE	532.89	4	133.22	48.27	P<0.01
REPN BY AGE	81.6	16	5.09	1.84	
AGE BY PACK	27.42	4	6.86	2.48	
REP BY AGE BY PACK	44.17	16	2.76		
TOTAL	686.08	40			
TASTER	279.08	7	39.87	1.79	
PACK BY TASTER	43.98	7	6.28	0.28	
AGE BY TASTER	195.43	28	6.98	3.18	P<0.01
REPN BY TASTER	281.50	28	10.05	0.45	
ERROR C	6219.1	280	22.21		
TOTAL	7740.4	399			

TESTS OF SIGNIFICANCE FOR D13 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F ratio	Significance
REPN	110.37	4	27.59	3.46	
PACK	10.11	1	10.11	1.27	
PACK BY REPN	31.88	4	7.97		
TOTAL	152.36	9			
AGE	357.35	4	89.34	14.86	P<0.01
REPN BY AGE	122.85	16	7.67	1.28	
AGE BY PACK	25.65	4	6.41	1.07	
REP BY AGE BY PACK	96.22	16	6.01		
TOTAL	602.07	40			
TASTER	350.62	7	50.09	2.65	P<0.01
PACK BY TASTER	25.45	7	3.64	0.19	
AGE BY TASTER	141.07	28	5.04	0.27	
REPN BY TASTER	307.67	28	10.99	0.58	
ERROR C	5283.07	280	18.87		
TOTAL	6862.31	399			

APPENDIX 9

SUMMARY TABLES FOR THE ANALYSIS OF VARIANCE OF CHICKEN A LA KING.

Key: **The 18 sensory attributes of chicken a la king:**

APPEARANCE

Sauce:

A1	Granular/pastey	Absent	Present
A2	Gelatinous texture	Not set	Well set
A3	Depth of colour	Weak	Full
A4	Sauces coating properties (peas/pimentos)	No coating	Coats well
A5	Appearance of meat	Broken up	Whole
A6	Shade of pea colour	Fresh pea colour	olive khaki
A7	Pea colour range	Not variable	Variable
A8	Surface oil on reheated sample	Absent	Present
ODOUR			
A9	Sauce odour	Fresh	Stale
A10	Depth of chicken odour	Weak	Strong
TEXTURE			
A11	Sauce texture	Coarse	Smooth
A12	Meat texture	Breaks down readily	Chewy
A13	Variability of pea texture	Not variable	Variable
FLAVOUR			
A14	Staleness	Absent	Present
A15	Acidic flavour	Absent	Present
A16	Degree of sweetness	Weak	Strong
A17	Degree of saltiness	Weak	Strong
A18	Chicken flavour of meat	Bland	Full

R: Replications
P: Packaging
T: Judges (tasters
A: Storage life (age in days)

MODEL ONE; 3 levels of packaging and 5 levels of storage life

TESTS OF SIGNIFICANCE FOR A1 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	50.38	4	12.59	17.38	P<0.01
PACK	6.57	2	3.29	0.45	
RxP	57.93	8	7.24		
Total	114.87				
AGE	170.77	2	85.39	9.72	P<0.01
RxA	56.04	8	7.00	0.80	
PxA	14.18	4	3.55	0.40	
RxPxA	140.52	16	8.78		
Total	381.51				
T	154.34	5	30.87	1.18	
RxT	148.38	20	7.42	0.20	
PxT	75.57	10	7.55	0.98	
AxT	358.97	10	35.90	0.99	
(c)	6575.76	180	36.53		
	7313.01				

Grand total 7809.39

TESTS OF SIGNIFICANCE FOR A2 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	54.83	4	13.71	1.33	
PACK	22.89	2	11.44	1.11	
RxP	82.20	8	10.27		
Total	159.92				
AGE	120.60	2	60.30	6.75	p<0.01
RxA	50.31	8	6.29	0.70	
PxA	8.17	4	2.04	0.23	
RxPxA	142.90	16	8.93		
Total	321.98				
T	296.35	5	59.27	1.41	
RxT	38.35	20	1.92	.04	
PxT	49.99	10	4.99	.12	
AxT	388.79	10	25.92	.92	
c)error	7572.74	180	52.07		
Total	8346.22				

Grand total 8828.12

TESTS OF SIGNIFICANCE FOR A3 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	53.11	4	13.28	6.36	p<0.025
PACK	56.49	2	28.24	13.53	p<0.01
RxP	16.70	8	2.09		
Total	136.30				
AGE	452.69	2	226.35	36.51	p<0.01
RxA	18.64	8	2.33	0.37	
PxA	8.80	4	2.02	0.32	
RxPxA	99.20	16	6.2		
Total	578.61				
T	338.00	5	67.60	1.68	
RxT	126.01	20	6.30	0.16	
PxT	49.72	10	4.97	0.12	
AxT	436.74	10	43.67	1.08	
(c)	7249.27	180	40.27		
	8199.75				
Grand total	8904.66				

TESTS OF SIGNIFICANCE FOR A4 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	34.54	4	8.64	2.19	
PACK	4.06	2	2.30	0.51	
RxP	31.51	8	3.94		
Total	70.11				
AGE	354.10	2	177.05	32.54	p<0.01
RxA	32.77	8	4.10	0.75	
PxA	2.50	4	.63	0.11	
RxPxA	87.04	16	5.44		
Total	476.40				
T	192.50	5	38.50	0.87	
RxT	123.21	20	6.16	0.14	
PxT	9.39	10	0.94	0.02	
AxT	242.13	10	24.21	0.55	
(c)	7946.14	180	44.14		
	8513.37				
Grand total	9059.88				

TESTS OF SIGNIFICANCE FOR A5 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	69.40	4	17.35	28.44	p<0.01
PACK	17.46	2	8.73	14.29	p<0.01
RxP	4.88	8	.61		
Total	91.73				
AGE	204.01	2.	102.01	5.33	p<0.025
RxA	54.44	8	6.80	0.35	
PxA	12.33	4	3.08	0.16	
RxPxA	35.31	16	19.13		
Total	306.08				
T	128.98	5	25.80	0.50	
RxT	142.68	20	7.13	0.14	
PxT	92.61	10	9.26	0.18	
AxT	178.00	10	17.80	0.35	
(c)	9214.85	180	51.19		
	9757.11				
Grand total	10154.92				

TESTS OF SIGNIFICANCE FOR A6 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	25.34	4	6.33	2.04	
PACK	17.04	2	8.52	2.75	
RxP	24.80	8	3.10		
Total	69.17				
AGE	335.79	2	167.89	35.98	P<.001
RxA	33.34	8	4.17	0.89	
PxA	38.38	4	9.60	2.05	
RxPxA	74.65	16	4.66		
Total	482.16				
T	41.90	5	8.38	0.38	
RxT	85.51	20	3.84	0.17	
PxT	18.14	10	1.81	0.08	
AxT	82.65	10	8.26	0.37	
(c)	3998.61	180	22.21		
	4226.81				
Grand total	4776.14				

TESTS OF SIGNIFICANCE FOR A7 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	8.32	4	2.08	0.27	
PACK	26.51	2	13.26	1.35	
RxP	78.34	8	9.79		
Total	113.17				
AGE	239.84	2	119.92	7.61	P<0.01
RxA	51.02	8	6.38	0.40	
PxA	6.08	4	1.52	0.10	
RxPxA	252.71	16	15.75		
Total	319.65				
T	208.35	5	41.67	1.28	
RxT	130.65	20	6.53	0.20	
PxT	41.08	10	4.11	0.13	
AxT	277.42	10	27.74	0.85	
(c)	5843.95	180	32.46		
	6501.45				
Grand total	6934.27				

TESTS OF SIGNIFICANCE FOR A8 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	132.24	4	33.60	5.06	P<0.025
PACK	45.84	2	22.92	3.51	
RxP	52.27	8	6.53		
total	230.35				
AGE	68.42	2	34.21	3.66	P<0.05
RxA	60.25	8	7.53	0.81	
PxA	74.11	4	18.53	1.99	
RxPxA	149.25	16	9.33		
Total	352.03				
T	22.67	5	4.53	0.11	
RxT	150.35	20	7.52	0.18	
PxT	53.34	10	5.33	0.13	
AxT	97.74	10	9.77	0.24	
(c)	7391.44	180	41.06		
	7662.20				
Grand total	8244.58				

TESTS OF SIGNIFICANCE FOR A9 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	88.70	4	22.17	2.01	
PACK	14.81	2	7.40	0.67	
RxP	88.46	8	11.06		
Total	191.95				
AGE	119.06	2	59.53	7.89	P<.01
RxA	31.15	8	3.89	0.52	
PxA	8.16	4	2.04	0.27	
RxPxA	120.67	16	7.54		
Total	279.03				
T	139.11	5	27.82	0.73	
RxT	75.81	20	3.79	0.10	
PxT	19.87	10	1.99	0.05	
AxT	179.53	10	17.95	0.47	
(c)	6865.02	180	38.14		
	7279.34				
Grand total	7750.32				

TESTS OF SIGNIFICANCE FOR A10 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	19.13	4	4.78	0.70	
PACK	17.22	2	8.61	1.26	
RxP	54.78	8	6.85		
Total	91.13				
AGE	38.25	2	19.13	1.80	
RxA	34.43	8	4.30	0.40	
PxA	18.15	4	4.54	0.43	
RxPxA	170.27	16	10.64		
Total	261.10				
T	108.22	5	21.64	0.86	
RxT	89.63	20	4.48	0.18	
PxT	24.94	10	2.49	0.10	
AxT	156.27	10	15.63	0.62	
(c)	4501.26	180	25.01		
	4880.32				
Grand total	5232.55				

TESTS OF SIGNIFICANCE FOR A11 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	21.28	4	5.32	1.78	
PACK	8.51	2	4.25	1.42	
RxP	23.90	8	2.99		
Total	53.67				
AGE	63.74	2	31.87	7.95	P<0.01
RxA	13.89	8	1.74	0.43	
PxA	11.64	4	2.91	0.72	
RxPxA	64.23	16	4.01		
Total	153.50				
T	415.53	5	83.11	1.24	
RxT	57.68	20	2.88	0.04	
PxT	54.41	10	5.44	0.08	
AxT	456.06	10	45.61	0.68	
(c)	12067.12	180	67.03		
	13050.80				
Grand total	13257.97				

TESTS OF SIGNIFICANCE FOR A12 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	129.86	4	32.46	3.83	
PACK	11.70	2	5.84	0.69	
RxP	67.80	8	8.47		
Total	209.35				
AGE	10.75	2	5.37	0.55	
RxA	81.94	8	10.24	1.04	
PxA	19.69	4	4.92	0.50	
RxPxA	157.03	16	9.81		
Total	269.41				
T	82.27	5	16.45	0.37	
RxT	85.44	20	4.27	0.10	
PxT	62.67	10	6.27	0.14	
AxT	129.93	10	12.99	0.29	
(c)	7899.69	180	43.89		
	8260.00				
Grand total	8738.76				

TESTS OF SIGNIFICANCE FOR A13 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	90.79	4	22.69	2.93	
PACK	11.94	2	5.97	0.77	
RxP	61.91	8	7.73		
Total	164.65				
AGE	10.05	2	5.02	0.44	
RxA	48.26	8	6.03	0.53	
PxA	35.33	4	8.83	0.78	
RxPxA	181.86	16	11.37		
Total	275.50				
T	53.39	5	10.67	0.24	
RxT	157.26	20	7.86	0.17	
PxT	88.89	10	8.89	0.19	
AxT	175.66	10	17.56	0.39	
(c)	8165.15	180	45.36		
	8640.35				
Grand total	9080.50				

TESTS OF SIGNIFICANCE FOR A14 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	57.98	4	14.49	2.86	
PACK	24.16	2	12.08	2.38	
RxP	40.51	8	5.06		
Total	122.65				
AGE	62.19	2	31.09	6.04	p<0.025
RxA	26.69	8	3.33	0.65	
PxA	17.74	4	4.43	0.86	
RxPxA	82.30	16	5.14		
Total	188.92				
T	441.65	5	88.33	2.46	
RxT	84.16	20	4.21	0.12	
PxT	42.64	10	4.26	0.12	
AxT	542.26	10	54.23	1.51	
(c)	6460.52	180	35.89		
	7571.23				
Grand total	7882.80				

TESTS OF SIGNIFICANCE FOR A15 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	45.71	4	11.42	2.82	
PACK	6.23	2	3.11	0.77	
RxP	32.38	8	4.04		
Total	84.32				
AGE	.92	2	.45	0.05	
RxA	90.25	8	11.28	1.34	
PxA	7.61	4	1.90	0.22	
RxPxA	134.83	16	8.43		
Total	233.60				
T	347.25	5	69.45	2.48	
RxT	195.04	20	9.75	0.35	
PxT	128.95	10	12.89	0.46	
AxT	425.11	10	42.51	1.52	
(c)	5047.18	180	28.04		
	6143.53				
Grand total	6461.45				

TESTS OF SIGNIFICANCE FOR A16 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	81.83	4	20.45	3.03	
PACK	12.87	2	6.43	0.95	
RxP	53.99	8	6.74		
Total	148.69				
AGE	11.86	2	5.92	1.02	
RxA	25.87	8	3.23	0.55	
PxA	9.34	4	2.33	0.40	
RxPxA	92.80	16	5.80		
Total	139.86				
T	294.32	5	58.86	2.26	
RxT	140.87	20	7.04	0.27	
PxT	85.20	10	8.52	0.33	
AxT	390.53	10	39.05	1.50	
(c)	4684.90	180	26.03		
	5595.82				
Grand total	5884.37				

TESTS OF SIGNIFICANCE FOR A17 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	16.19	4	4.04	0.75	
PACK	10.41	2	5.20	0.96	
RxP	43.29	8	5.41		
Total	69.89				
AGE	25.74	2	12.87	1.68	
RxA	40.18	8	5.02	0.65	
PxA	1.11	4	.27	0.03	
RxPxA	122.73	16	7.67		
Total	189.75				
T	267.03	5	53.40	1.86	
RxT	174.04	20	8.70	0.30	
PxT	65.27	10	6.53	0.23	
AxT	331.06	10	33.11	1.15	
(c)	5171.64	180	28.73		
	6009.04				
Grand total	6268.67				

TESTS OF SIGNIFICANCE FOR A18 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Sig.
REPN	53.68	4	13.42	1.18	
PACK	24.17	2	12.09	1.06	
RxP	91.23	8	11.40		
Total	169.08				
AGE	45.92	2	22.96	2.29	
RxA	33.56	8	4.20	0.42	
PxA	9.06	4	2.26	0.22	
RxPxA	160.46	16	10.03		
Total	249.00				
T	281.99	5	56.40	1.75	
RxT	287.85	20	14.39	0.45	
PxT	64.61	10	6.46	0.20	
AxT	312.15	10	31.21	0.97	
(c)	5789.77	180	32.16		
	6736.36				
Grand total	7154.45				

MODEL TWO: 2 levels of packaging and 5 levels of storage life

TESTS OF SIGNIFICANCE FOR A1 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	45.70	4	11.42	1.05	
PACK	6.14	1	6.13	0.18	
RxP	43.72	4	10.93		
Total	95.56				
AGE	184.30	4	46.07	7.28	
RxA	100.19	16	6.26	0.99	
PxA	29.88	4	7.47	1.18	
RxPxA	101.21	16	6.32		
Total	415.58				
T	297.21	5	59.44	1.49	
RxT	137.18	20	6.86	0.72	
PxT	51.41	5	10.28	0.26	
AxT	622.98	20	31.15	0.78	
c)	7963.43	200	39.82		
Total	9072.21				
Grand total	9583.35				

TESTS OF SIGNIFICANCE FOR A2 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	33.37	4	8.34	2.22	
PACK	.87	1	.87	0.23	
RxP	14.99	4	3.75		
Total	49.22				
AGE	238.29	4	59.57	10.52	P<0.01
RxA	162.45	16	10.15	1.79	
PxA	12.49	4	3.12	0.55	
RxPxA	90.61	16	5.66		
Total	503.83				
T	366.34	5	73.27	1.51	
RxT	99.55	20	4.98	0.10	
PxT	31.13	5	6.23	0.13	
AxT	502.96	20	25.15	0.52	
c)	9680.03	200	48.40		
Total	10680.01				
Grand total	11233.06				

TESTS OF SIGNIFICANCE FOR A3 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	91.42	4	22.85	6.33	
PACK	20.69	1	20.68	5.73	
RxP	14.45	4	3.61		
Total	126.56				
AGE	599.53	4	149.88	24.47	P<0.01
RxA	44.51	16	2.78	0.51	
PxA	35.99	4	9.00	1.65	
RxPxA	87.31	16	5.46		
Total	767.34				
T	199.73	5	39.94	1.18	
RxT	164.96	20	8.25	0.24	
PxT	19.05	5	3.81	0.11	
AxT	345.43	20	17.27	0.51	
c)	6764.83	200	33.82		
Total	7494.00				
Grand total	8387.90				

TESTS OF SIGNIFICANCE FOR A4 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	18.14	4	4.53	0.82	
PACK	9.37	1	9.36	1.71	
RxP	21.98	4	5.47		
Total	49.48				
AGE	405.60	4	101.40	24.81	P<0.001
RxA	94.69	16	5.92	1.45	
PxA	27.75	4	6.94	1.70	
RxPxA	65.39	16	4.09		
Total	593.43				
T	171.37	5	34.27	0.93	
RxT	111.03	20	5.55	0.15	
PxT	26.72	5	5.34	0.14	
AxT	271.18	20	13.56	0.37	
c)	7340.13	200	36.70		
Total	7920.43				
Grand total	8563.34				

TESTS OF SIGNIFICANCE FOR A5 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	47.97	4	11.99	9.22	P<0.05
PACK	32.03	1	32.03	24.65	P<0.01
RxP	5.18	4	1.30		
Total	85.18				
AGE	268.44	4	67.11	16.59	P<0.05
RxA	114.36	16	7.15	1.77	
PxA	44.53	4	11.11	2.74	
RxPxA	64.73	16	4.04		
Total	492.06				
T	131.99	5	26.40	0.61	
RxT	154.42	20	7.72	0.18	
PxT	11.70	5	2.34	0.05	
AxT	280.13	20	14.01	0.32	
c)	8630.70	200	43.15		
Total	9208.94				
Grand total	9786.18				

TESTS OF SIGNIFICANCE FOR A6 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	34.48	4	8.62	4.56	
PACK	77.03	1	77.02	40.76	P<0.01
RxP	7.56	4	1.89		
Total	119.08				
AGE	476.31	4	119.07	24.26	P<0.001
RxA	92.57	16	5.78	1.19	
PxA	114.33	4	28.58	5.87	
RxPxA	77.89	16	4.87		
Total	161.10				
T	19.36	5	3.87	0.14	
RxT	78.95	20	3.95	0.14	
PxT	31.13	5	6.22	0.22	
AxT	124.61	20	6.23	0.22	
c)	5697.66	200	28.49		
Total	5951.71				
Grand total	6831.89				

TESTS OF SIGNIFICANCE FOR A7 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	32.36	4	8.09	1.36	
PACK	.09	1	.09	0.02	
RxP	23.87	4	5.96		
Total	56.35				
AGE	220.40	4	55.10	5.62	
RxA	141.90	16	8.86	0.90	
PxA	16.66	4	4.17	0.42	
RxPxA	156.87	16	9.80		
Total	535.84				
T	349.83	5	69.96		
2.31					
RxT	220.34	20	11.02	0.36	
PxT	39.40	5	7.88	0.26	
AxT	500.10	20	25.01	0.83	
c)	6052.73	200	30.26		
Total	7162.40				

Grand total 7754.59

TESTS OF SIGNIFICANCE FOR A8 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	16.45	4	4.11	0.86	
PACK	32.91	1	32.91	6.90	
RxP	19.08	4	4.77		
Total	68.44				
AGE	44.40	4	11.10	1.72	
RxA	157.17	16	9.82	1.52	
PxA	112.81	4	28.20	4.35	P<0.05
RxPxA	103.60	16	6.47		
Total	417.99				
T	32.35	5	6.47	0.14	
RxT	73.97	20	3.70	0.08	
PxT	37.28	5	7.46	0.16	
AxT	116.70	20	5.84	0.13	
c)	9052.46	200	42.56		
	9312.77				

Grand total 9799.20

TESTS OF SIGNIFICANCE FOR A9 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	59.52	4	14.87	0.07	
PACK	16.71	1	16.70	0.98	
RxP	68.17	4	17.04		
Total	144.40				
AGE	125.02	4	31.25	3.97	P<0.05
RxA	53.98	16	3.37	0.43	
PxA	23.37	4	5.84	0.74	
RxPxA	125.82	16	7.86		
Total	328.19				
T	67.81	5	13.56	0.32	
RxT	72.33	20	3.62	0.08	
PxT	8.13	5	1.62	0.04	
AxT	163.10	20	8.15	0.19	
c)	8505.23	200	42.53		
	8816.60				
Grand total	9289.19				

TESTS OF SIGNIFICANCE FOR A10 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	22.54	4	5.64	3.64	
PACK	16.61	1	16.62	10.72	P<0.05
RxP	6.21	4	1.55		
Total	45.38				
AGE	15.81	4	3.95	0.91	
RxA	56.18	16	3.51	0.81	
PxA	21.08	4	5.27	1.21	
RxPxA	69.60	16	4.35		
Total	162.67				
T	130.08	5	26.01	1.07	
RxT	96.95	20	4.85	0.20	
PxT	9.95	5	1.99	0.08	
AxT	239.80	20	11.99	0.49	
c)	4836.50	200	24.18		
	5313.28				
Grand total	5521.33				

TESTS OF SIGNIFICANCE FOR A11 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	34.01	4	8.50	3.05	
PACK	1.33	1	1.33	0.48	
RxP	11.15	4	2.78		
Total	46.50				
AGE	90.20	4	22.55	8.59	P<0.01
RxA	25.85	16	1.61	0.62	
PxA	13.96	4	3.49	1.33	
RxPxA	41.99	16	2.62		
Total	172.00				
T	486.80	5	97.36	1.57	
RxT	79.62	20	3.98	0.06	
PxT	23.02	5	4.60	0.07	
AxT	563.43	20	28.17	0.45	
c)	12390.25	200	61.95		
	13543.12				

Grand total 13761.62

TESTS OF SIGNIFICANCE FOR A12 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	34.96	4	8.74	1.95	
PACK	.02	1	.02	0.01	
RxP	17.95	4	4.48		
Total	52.94				
AGE	7.88	4	1.97	0.26	
RxA	148.16	16	9.26	1.21	
PxA	17.68	4	4.42	1.74	
RxPxA	122.93	16	7.68		
Total	296.65				
T	81.95	5	16.38	0.37	
RxT	35.61	20	1.78	0.04	
PxT	37.08	5	7.42	0.17	
AxT	188.09	20	9.40	0.21	
c)	8793.33	200	43.97		
	9136.06				

Grand total 9485.65

TESTS OF SIGNIFICANCE FOR A13 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	111.36	4	27.83	2.46	
PACK	38.27	1	38.27	3.37	
RxP	45.36	4	11.34		
Total	194.99				
AGE	71.35	4	17.83	1.37	
RxA	75.63	16	4.72	0.36	
PxA	58.80	4	14.70	1.13	
RxPxA	207.76	16	12.99		
Total	413.54				
T	55.14	5	11.02	0.23	
RxT	269.63	20	13.48	0.28	
PxT	60.32	5	12.06	0.25	
AxT	235.20	20	11.76	0.24	
c)	9742.77	200	48.71		
	10363.06				

Grand total 10971.59

TESTS OF SIGNIFICANCE FOR A14 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	99.89	4	24.97	3.20	
PACK	21.01	1	21.00	2.69	
RxP	31.20	4	7.80		
Total	152.10				
AGE	89.37	4	22.34	6.21	P<0.01
RxA	65.10	16	4.06	1.13	
PxA	71.20	4	17.80	4.95	
RxPxA	57.52	16	3.59		
Total	283.19				
T	377.16	5	75.43	1.86	
RxT	122.83	20	6.14	0.15	
PxT	12.96	5	2.58	0.06	
AxT	549.38	20	27.47	0.68	
c)	8117.19	200	40.58		
	9119.53				

Grand total 9614.81

TESTS OF SIGNIFICANCE FOR A15 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	55.49	4	13.87	1.53	
PACK	2.37	1	2.37	0.26	
RxP	36.14	4	9.03		
Total	94.00				
AGE	33.55	4	8.39	0.98	
RxA	125.14	16	7.82	0.91	
PxA	13.88	4	3.47	0.40	
RxPxA	137.12	16	8.57		
Total	309.69				
T	223.69	5	44.74	1.38	
RxT	191.26	20	9.56	0.30	
PxT	7.90	5	1.58	0.05	
AxT	311.51	20	15.58	0.48	
c)	6467.26	200	32.34		
	7201.62				
Grand total	7605.31				

TESTS OF SIGNIFICANCE FOR A16 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	52.42	4	13.10	4.64	
PACK	1.97	1	1.97	0.70	
RxP	11.30	4	2.82		
Total	65.69				
AGE	31.62	4	7.90	1.74	
RxA	80.69	16	5.04	1.11	
PxA	16.54	4	4.13	0.91	
RxPxA	72.83	16	4.55		
Total	201.68				
T	326.43	5	65.28	2.12	
RxT	88.21	20	4.41	0.14	
PxT	11.96	5	2.39	0.08	
AxT	465.67	20	23.28	0.76	
c)	6161.20	200	30.81		
	7053.47				
Grand total	7320.84				

TESTS OF SIGNIFICANCE FOR A17 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	22.53	4	5.63	0.77	
PACK	.84	1	.84	0.12	
RxP	29.20	4	7.30		
Total	52.57				
AGE	14.77	4	3.69	0.55	
RxA	61.49	16	3.84	0.58	
PxA	1.98	4	0.49	0.07	
RxPxA	106.06	16	6.63		
Total	184.30				
T	217.21	5	43.44	1.38	
RxT	193.59	20	9.68	0.31	
PxT	28.77	5	5.75	0.18	
AxT	403.34	20	20.17	0.64	
c)	6285.64	200	31.43		
	7128.55				

Grand total 7365.42

TESTS OF SIGNIFICANCE FOR A18 USING SEQUENTIAL SUMS OF SQUARES

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Significance
REPN	261.75	4	65.44	2.05	
PACK	7.78	1	7.78	0.24	
RxP	127.76	4	31.94		
Total	397.29				
AGE	101.77	4	25.44	0.53	
RxA	611.74	16	38.23	0.80	
PxA	238.80	4	59.70	1.24	
RxPxA	766.15	16	47.88		
Total	1718.46				
T	168.37	5	33.67	0.53	
RxT	1329.59	20	66.48	1.04	
PxT	10.56	5	2.11	0.03	
AxT	1175.99	20	58.80	0.92	
c)	12825.41	200	64.13		
	155.9.92				

Grand total 17625.67

APPENDIX 10

THE SUMMARY TABLES FROM THE STEPWISE DISCRIMINANT ANALYSES (SDA)

Sample groups entered in each analyses:

SDA of chicken drumsticks

1. 13 groups of samples: cling wrapped samples stored for 4 and 7 days,
   vacuum packed samples stored for 4, 7, 11 and 14 days,
   MAP drumsticks stored for 4, 7, 11 and 14 days
   and 3 groups of fresh drumsticks (one for each packaging type).

2. 11 groups of samples: cling wrapped samples stored for 4 and 7 days,
   vacuum packed samples stored for 4, 7, 11 and 14 days,
   MAP drumsticks stored for 4, 7, 11 and 14 days
   and 1 groups of fresh drumsticks (three groups combined into one).

3. 11 groups of samples: cling wrapped samples stored for 4 and 7 days,
   vacuum packed samples stored for 4, 7 and 11 days,
   MAP drumsticks stored for 4, 7 and 11 days
   and 3 groups of fresh drumsticks (one for each packaging type).

4. 9 groups of samples: cling wrapped samples stored for 4 and 7 days,
   vacuum packed samples stored for 4, 7 and 11 days,
   MAP drumsticks stored for 4, 7 and 11 days
   and 3 groups of fresh drumsticks (three groups combined into one).

SDA of chicken a la king

5. 13 groups of samples: cling wrapped samples stored for 4 and 7 days,
   vacuum packed samples stored for 4, 7, 11 and 14 days,
   MAP a la king stored for 4, 7, 11 and 14 days
   and 3 groups of fresh a la king (one for each packaging type).

6. 11 groups of samples: cling wrapped samples stored for 4 and 7 days,
   vacuum packed samples stored for 4, 7, 11 and 14 days,
   MAP a la king stored for 4, 7, 11 and 14 days
   and 1 groups of fresh a la king (three groups combined into one).

Key of sensory attributes of chicken drumsticks

D1. Shrivelled
D2. Brightness
D3. Dry appearance of flesh
D4. Compact appearance of flesh
D5. Fried chicken odour
D6. Rancid odour
D7. Bland odour
D8. Juiciness of flesh
D9. Degree of chewing
D10. First bite
D11. Fried chicken odour
D12. Rancid flavour
D13. Bland flavour

Key of sensory attributes of chicken a la king

A1. Granular/pastey
A2. Gelatinous texture
A3. Depth of colour
A4. Sauces coating properties
A5. Appearance of meat
A6. Shade of pea colour
A7. Pea colour range
A8. Surface oil on reheated sample
A9. Sauce odour
A10. Depth of chicken odour
A11. Sauce texture
A12. Meat texture
A13. Variability of pea texture
A14. Staleness
A15. Acidic flavour
A16. Degree of sweetness
A17 Degree of saltiness
A18. Chicken flavour of meat

MODEL 1

Stepwise discriminant analysis of chicken drumsticks; 13 groups of samples

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS' LAMBDA	SIG.	LABEL
1	D10		1	.428247	.0000	FRIED CHICKEN FLAVOUR
2	D7		2	.358647	.0000	JUICINESS OF FLESH
3	D6		3	.312636	.0000	RANCID ODOUR
4	D1		4	.276758	.0000	DEGREE OF SHRIVELLING
5	D9		5	.258027	.0000	FIRST BITE
6	D11		6	.242890	.0000	RANCID FLAVOUR
7	D3		7	.230225	.0000	DRY APPEARANCE OF FLESH
8	D5		8	.218807	.0000	FRIED CHICKEN ODOUR
9	D13		9	.211051	.0000	BLAND ODOUR
10	D2		10	.204051	.0000	BRIGHTNESS
11	D4		11	.198704	.0000	COMPACT APPEARANCE OF FLESH
12	D12		12	.193579	.0000	BLAND FLAVOUR

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	: AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
					: 0	.1935879	871.09	144	.0000
1*	2.01935	77.34	77.34	.8177835	: 1	.5844514	284.92	121	.0000
2*	.33457	12.82	90.15	.5006940	: 2	.7799908	131.32	100	.0182
3*	.11243	4.33	94.48	.3186081	: 3	.8681140	75.030	81	.6553
4	.06232	2.38	96.85	.2416511	: 4	.9219516	43.110	64	.9791
5	.02752	1.05	97.91	.1636537	: 5	.9473234	28.708	49	.9909
6	.02542	.97	98.88	.1574483	: 6	.9716045	15.391	36	.9990
7	.01612	.62	99.50	.1259547	: 7	.9870638	6.9074	25	.9999
8	.00644	.25	99.75	.0799884	: 8	.9934199	3.5023	16	.9995
9	.00384	.15	99.89	.0620224	: 9	.9972551	1.4577	9	.9974
10	.00130	.07	99.96	.0424334	: 10	.9990550	.50158	4	.9733
11	.00094	.04	100.00	.0305676	: 11	.9999893	.56635E-02	1	.9400
12	.00031	.00	100.00	.0032674	:				

* MARKS THE 3 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.

A10.

MODEL 1

Stepwise discriminant analysis of chicken drumsticks; 13 groups of samples

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3
D1	-.06976	.68514	-.07640
D2	.02290	.13419	-.30065
D3	-.13127	-.03044	-.36653
D4	-.08900	-.27573	.13037
D5	.23302	-.21935	.28825
D6	-.13761	.16136	.59871
D7	.30856	.26383	-.29348
D9	-.09256	-.38972	.47536
D10	.46804	-.13053	.26954
D11	-.08127	.52609	-.10927
D12	-.03552	-.07613	-.39558
D13	-.07302	-.22629	-.03533

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3
1	2.62265	.15741	.12299
2	-.35555	-.81149	-.33548
3	-.68445	-1.08476	.11799
4	-1.10337	-.87052	.27110
5	-1.10275	-.23779	.21148
6	2.22654	.07435	-.07918
7	-.10366	.46220	-.83574
8	-.44372	-.08032	-.43226
9	-1.05015	.65673	.17434
10	-1.08631	.51559	-.18637
11	2.53830	-.13545	.22139
12	-.60558	.45067	.20474
13	-1.02921	.69241	.39606

MODEL 2

Stepwise discriminant analysis of chicken drumsticks; 11 groups of samples

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3
D1	-.07181	.66882	-.07545
D2	.02621	.13601	-.30343
D3	-.12434	-.01073	-.36415
D4	-.09299	-.27422	.11764
D5	.22536	-.22565	.27700
D6	-.14249	.17217	.53702
D7	.31167	.27788	-.31176
D9	-.09240	-.37677	.43457
D10	.47240	-.12609	.30818
D11	-.07769	.52243	-.10163
D12	-.03176	-.08253	-.38750
D13	-.07172	-.23873	-.06437

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3
1	2.43[illegible]	.02625	.10[illegible]
2	-.35232	-.81832	-.37357
3	-.68[illegible]	-1.08734	.12476
4	-1.10[illegible]	-.85232	.27605
5	-1.10[illegible]	-.23332	.20334
6	-.09[illegible]	.45065	-.81779
7	-.43[illegible]	-.08542	-.42759
8	-1.04[illegible]	.66446	.10410
9	-1.08[illegible]	.518[illegible]	-.13[illegible]
10	-.60931	.44678	.20236
11	-1.031[illegible]	.69411	.38[illegible]

MODEL 2

Stepwise discriminant analysis of chicken drumsticks; 11 groups of samples

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS' LAMBDA	SIG.	LABEL
1	D10		1	.429641	.0000	FRIED CHICKEN FLAVOUR
2	D7		2	.360150	.0000	JUICINESS OF FLESH
3	D6		3	.313948	.0000	RANCID ODOUR
4	D1		4	.279719	.0000	DEGREE OF SHRIVELLING
5	D9		5	.262557	.0000	FIRST BITE
6	D11		6	.245996	.0000	RANCID FLAVOUR
7	D3		7	.235209	.0000	DRY APPEARANCE OF FLESH
8	D5		8	.224662	.0000	FRIED CHICKEN ODOUR
9	D13		9	.217138	.0000	BLAND ODOUR
10	D2		10	.210113	.0000	BRIGHTNESS
11	D4		11	.204322	.0000	
12	D12		12	.199609	.0000	BLAND FLAVOUR

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	: AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
					: 0	.1996039	956.46	120	.0000
1*	1.99935	77.95	77.95	.8166523	: 1	.5986993	272.66	99	.0000
2*	.32348	12.85	90.80	.4978227	: 2	.7959537	121.29	80	.0020
3*	.10933	4.25	95.04	.3133554	: 3	.8926251	56.360	63	.3619
4	.05960	2.32	97.36	.2359825	: 4	.9351434	35.640	48	.9066
5	.02502	.98	98.34	.1562329	: 5	.9585402	22.536	35	.9693
6	.02033	.80	99.14	.1418507	: 6	.9782236	11.702	24	.9931
7	.01356	.53	99.67	.1161052	: 7	.9915937	4.4835	15	.9956
8	.00595	.15	99.82	.0625964	: 8	.9954913	2.4018	8	.9662
9	.00553	.15	99.97	.0517983	: 9	.9993077	.36809	3	.9469
10	.00069	.03	100.00	.0263119	:				

* MARKS THE 3 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.

A10.6

MODEL3

Stepwise discriminant analysis of chicken drumsticks; 11 groups of samples

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3
D1	-.05069	.69214	-.11916
D3	-.15144	-.09983	-.34245
D4	-.07414	-.28121	.16200
D5	.23018	-.13362	.21851
D6	-.14529	.12264	.64460
D7	.93462	.24578	-.34007
D9	-.12147	-.33217	.49616
D10	.43469	-.13069	.22204
D11	-.10685	.58574	-.25748
D12	-.06217	-.00357	-.65349
D13	-.04251	-.24465	-.03242

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3
1	2.43351	.18491	.0[illegible]
2	-.50277	-.79835	-.4[illegible]
3	-.87085	-1.07[illegible]	.2428[illegible]
4	-1.30585	-.80921	.2933[illegible]
5	2.02784	.05[illegible]	-.04[illegible]
6	-.34921	.45960	-.93154
7	-.62[illegible]	-.04[illegible]	-.43[illegible]
9	-1.25[illegible]	.72[illegible]	.1[illegible]
10	2.33085	-.15[illegible]	.25[illegible]
12	-.79[illegible]	.45[illegible]	.2[illegible]
13	-1.32[illegible]	.74[illegible]	.37[illegible]

MODEL 3

Stepwise discriminant analysis of chicken drumsticks; 11 groups of samples

SUMMARY TABLE

STEP	ACTION ENTERED/REMOVED	VARS IN	WILKS' LAMBDA	SIG.	LABEL
1	D10	1	.430563	.0000	FRIED CHICKEN FLAVOUR
2	D7	2	.353505	.0000	JUICINESS OF FLESH
3	D11	3	.298655	.0000	RANCID FLAVOUR
4	D1	4	.263378	.0000	DEGREE OF SHRIVELLING
5	D9	5	.237851	.0000	FIRST BITE
6	D6	6	.224437	.0000	RANCID ODOUR
7	D3	7	.212429	.0000	DRY APPEARANCE OF FLESH
8	D5	8	.203916	.0000	FRIED CHICKEN ODOUR
9	D12	9	.194419	.0000	BLAND FLAVOUR
10	D4	10	.183875	.0000	COMPACT APPEARANCE OF FLESH
11	D13	11	.183959	.0000	BLAND ODOUR

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
					0	.1839385	765.31	110	.0000
1*	2.10956	77.16	77.16	.8236574	1	.5719636	252.52	90	.0000
2*	.36936	13.53	90.70	.5196779	2	.7335686	110.23	72	.0025
3*	.13216	4.84	95.56	.3424513	3	.8376910	53.847	56	.5568
4	.05812	2.13	97.68	.2343724	4	.9392864	28.311	42	.9475
5	.03176	1.16	98.85	.1754457	5	.9691170	14.179	30	.9936
6	.01815	.66	99.51	.1335966	6	.9867040	6.0501	20	.9988
7	.00975	.32	99.83	.0951461	7	.9953398	2.1113	12	.9992
8	.00391	.09	99.91	.0459871	8	.9975422	1.1123	6	.9810
9	.00124	.05	99.96	.0352319	9	.9987819	.55090	2	.7592
10	.00092	.04	100.00	.0349003					

* MARKS THE 3 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.

MODEL 4

Stepwise discriminant analysis of chicken drumsticks; 9 groups of samples

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS' LAMBDA	SIG.	LABEL
1	D10		1	.432090	.0000	FRIED CHICKEN FLAVOUR
2	D7		2	.353917	-.0000	JUICINESS OF FLESH
3	D11		3	.300331	.0000	RANCID FLAVOUR
4	D1		4	.265642	.0000	DEGREE OF SHRIVELLING
5	D9		5	.242490	.0000	FIRST BITE
6	D6		6	.229072	.0000	RANCID ODOUR
7	D3		7	.218056	.0000	DRY APPEARANCE OF FLESH
8	D12		8	.209356	.0000	BLAND FLAVOUR
9	D5		9	.201354	.0000	FRIED CHICKEN ODOUR
10	D4		10	.195794	.0000	
11	D13		11	.191682	.0000	BLAND ODOUR

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	: AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
					: 0	.1903824	750.21	88	.0000
1*	2.08514	77.89	77.89	.8221231	: 1	.5889369	239.33	70	.0000
2*	.36272	13.55	91.44	.5159183	: 2	.8025561	99.640	54	.0002
3*	.12732	4.76	96.19	.3360698	: 3	.9047379	45.350	40	.2587
4	.05397	2.02	98.21	.2262312	: 4	.9535654	21.540	28	.8021
5	.02638	.97	99.18	.1594262	: 5	.9784319	9.8773	18	.9358
6	.01615	.60	99.78	.1260693	: 6	.9942337	2.6197	10	.9890
7	.00655	.17	99.95	.0673627	: 7	.9987631	.56054	4	.9673
8	.00124	.05	100.00	.0351693	:				

* MARKS THE 3 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.

MODEL 4

Stepwise discriminant analysis of chicken drumsticks; 9 groups of samples

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3
D1	-.05351	.67223	-.10927
D2	-.14302	-.08854	-.34845
D4	-.08055	-.27923	.15276
D5	.22162	-.14447	.21730
D6	-.15074	.13609	.63230
D7	.33883	.26224	-.37033
D9	-.12069	-.31421	.50095
D10	.44058	-.12542	.25630
D11	-.10165	.58151	-.25856
D12	-.05773	-.01184	-.55136
D13	-.04251	-.26117	.00023

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3
1	2.26378	.02341	.10645
2	-.51768	-.79803	-.40174
3	-.87276	-1.07259	.25939
4	-1.30314	-.79659	.28548
5	-.24525	.44241	-.84447
6	-.62275	-.06996	-.41726
7	-1.24810	.71055	.10111
8	-.79175	.48853	.20856
9	-1.23519	.76930	.35464

MODEL 5

Stepwise discriminant analysis of chicken a la king; 13 groups of samples

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS' LAMBDA	SIG.	LABEL
1	A6		1	.637922	-.0000	SHADE OF PEA COLOUR
2	A4		2	.525545	.0000	SAUCE COATING
3	A9		3	.467501	.0000	SURFACE OIL
4	A3		4	.419063	.0000	DEPTH OF COLOUR
5	A2		5	.390302	.0000	GELATINOUS
6	A1		6	.369538	.0000	GRANULAR
7	A5		7	.354729	.0000	MEAT APPEARANCE
8	A14		8	.340492	.0000	STALE FLAVOUR
9	A18		9	.326957	.0000	CHICKEN FLAVOUR
10	A13		10	.313821	.0000	PEA TEXTURE
11	A7		11	.301400	.0000	RANGE OF PEA COLOUR

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	: AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
					: 0	.3013997	426.96	132	.0000
1*	.99629	64.81	64.81	.7064500	: 1	.6016821	180.86	110	.0000
2*	.23093	15.02	79.83	.4331333	: 2	.7406270	106.89	90	.1081
3*	.10093	6.57	86.39	.3027793	: 3	.8153769	72.661	72	.4560
4*	.07368	4.79	91.19	.2619631	: 4	.8754547	47.352	56	.7880
5*	.05476	3.56	94.75	.2278507	: 5	.9233936	28.373	42	.9465
6*	.03555	2.32	97.07	.1855412	: 6	.9563153	15.902	30	.9836
7*	.02562	1.67	98.73	.1580448	: 7	.9808142	6.8965	20	.9970
8*	.01036	.71	99.44	.1036329	: 8	.9914623	3.0525	12	.9952
9*	.00767	.50	99.94	.0872224	: 9	.9990629	.33377	6	.9993
10*	.00036	.06	100.00	.0293738	: 10	.9999257	.26469E-01	2	.9869
11*	.00007	.00	100.00	.0056225	:				

* MARKS THE 11 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.

MODEL5

Stepwise discriminant analysis of chicken a la king; 13 groups of samples

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3	FUNC 4	FUNC 5	FUNC 6	FUNC 7	FUNC 8	FUNC 9	FUNC 10	FUNC 11
A1	-.03441	-.37735•	.39511	.12866	-.05964	-.11500	-.44363	.41579	.36640	.58103	.02789
A2	-.30814•	-.02967	-.14251	-.25195	-.50837	.22277	.44257	-.11542	.53846	.05269	.37757
A3	.36655•	.09804	-.52957	.04347	.43178	-.10412	-.26104	.07118	.10078	.38144	.62692
A4	.25437	.33347•	.58521	-.37824	-.12993	.24630	.16454	.57105	.19700	-.24993	.10415
A5	.20800	-.12636	.14323	.28378	.14918	.46153	.48307	-.19468	.04700	.48094	-.47687
A6	-.56400•	.59973•	.09168	-.04272	.40743	.42926	-.12986	-.01959	-.02513	.31301	.13971
A7	-.03210	-.25110•	.20024	.17540	.41891	-.52588	.64788	.11159	-.18476	-.32522	.21649
A8	.24899	.62383•	.02025	.64681	-.13259	-.19265	.01038	-.05712	.29548	-.12532	-.20298
A13	-.03201	.25758•	-.41035	-.14014	-.33241	-.26340	.22999	.47353	-.35859	.38128	-.19234
A14	.02318	-.19813•	-.39057	.33357	.26704	.44699	-.05164	.57035	.08076	-.38000	-.13660
A18	.09683	-.16414•	.25746	.48021	-.34095	.25555	-.00243	.02237	-.56245	-.02825	.44286

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3	FUNC 4	FUNC 5	FUNC 6	FUNC 7	FUNC 8	FUNC 9	FUNC 10
1	1.99690	.39445	-.23450	.23555	.18232	.05509	.00857	-.09279	.12000	.02476
2	.18437	-.63399	-.19572	.22240	.30388	-.16241	-.05260	.02668	.05756	-.02157
3	-.29078	-.29066	-.09802	-.12283	.33041	-.03986	-.16312	-.01719	-.18762	.04583
4	-.55279	-.48147	.32190	.64014	-.31124	.17827	.01051	.01892	-.01913	.02332
5	-.53561	-.47646	-.42803	-.30409	-.38778	-.02092	-.15539	-.13200	.07455	.00942
6	1.77345	-.05212	.05334	-.21708	-.27442	.07248	-.18363	.17697	-.05374	-.02963
7	-.22491	.38533	-.05549	.11162	-.23702	-.49579	.16957	-.04474	-.06343	-.01020
8	-.55935	.41072	.36716	-.00622	.11149	.16662	-.13852	-.20504	-.03450	-.05410
9	-.87020	.75926	.43491	-.18110	.01197	-.08734	-.14344	.09224	.11259	.04144
10	-1.23168	.70932	-.67131	.13135	.02773	.22542	.07942	.11339	-.03369	-.01503
11	1.24612	.13807	.19989	-.12225	-.04180	.05761	.23110	-.03732	-.08965	.00819
12	-.49151	-.36302	.21486	-.00199	.21483	-.12637	.02167	.10739	.06371	-.03258
13	-.47215	-.48643	.11366	-.40948	.06544	.17684	.32822	.00051	.05132	.00721

GROUP	FUNC 11
1	.00444
2	-.01550
3	.00240
4	.00001
5	.00565
6	-.00459
7	-.00303
8	-.00301
9	-.00534
10	.00079
11	.00511
12	.02168
13	-.00851

MODEL6

Stepwise discriminant analysis of chicken a la king; 11 groups of samples

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS' LAMBDA	SIG.	LABEL
1	A6		1	.647237	.0000	SHADE OF PEA COLOUR
2	A4		2	.533557	.0000	SAUCE COATING
3	A3		3	.480701	.0000	SURFACE OIL
4	A5		4	.438870	.0000	DEPTH OF COLOUR
5	A2		5	.413514	.0000	GELATINOUS
6	A1		6	.390228	.0000	GRANULAR
7	A13		7	.375527	.0000	PEA TEXTURE
8	A18		8	.361070	.0000	CHICKEN FLAVOUR
9	A8		9	.347323	.0000	MEAT APPEARANCE
10	A14		10	.334455	.0000	STALE FLAVOUR
11	A7		11	.322473	.0000	RANGE OF PEA COLOUR

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
					0	.3224725	404.03	110	.0000
1*	.95154	65.88	65.88	.6932912	1	.6293506	165.31	90	.0000
2*	.22335	15.44	81.32	.4270482	2	.7697255	93.434	72	.0456
3*	.09474	6.56	87.88	.2941820	3	.8626511	61.119	56	.2973
4*	.06656	4.61	92.50	.2499870	4	.8988216	38.041	42	.6436
5*	.04305	2.98	95.48	.2031627	5	.9375178	23.033	30	.8139
6*	.03503	2.47	97.94	.1854803	6	.9709202	10.535	20	.9574
7*	.01900	1.34	99.29	.1379658	7	.9897598	3.6746	12	.9865
8*	.00736	.49	99.77	.0857254	8	.9967470	1.1632	6	.9787
9*	.00302	.21	99.98	.0548793	9	.9997580	.86417E-01	2	.9577
10*	.00024	.02	100.00	.0155575					

* MARKS THE 10 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.

MODEL6

Stepwise discriminant analysis of chicken a la king; 11 groups of samples

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1	FUNC 2	FUNC 3	FUNC 4	FUNC 5	FUNC 6	FUNC 7	FUNC 8	FUNC 9	FUNC 10
A1	-.03491	-.35352	.44543	.04379	-.03249	-.12089	-.26687	.69298	.28627	.38551
A2	-.29775	-.01715	-.23176	-.01189	-.65747	.26134	.37076	.20037	-.34402	-.02566
A3	.34025	.05928	-.46413	-.05301	.49696	-.13031	-.21736	.21088	.07734	.03100
A4	.27312	.38976	.45258	-.35062	-.24895	.25736	.36036	.46762	.14642	-.37233
A5	.21253	-.15793	.19899	.16571	.12511	.46650	.39806	-.21934	-.05529	.73240
A6	-.56840	.58563	.11080	-.21734	.38164	.41521	-.09917	-.00330	.09258	.20589
A7	-.01672	-.28035	.23473	-.03490	.34160	-.53500	.68238	-.27403	-.06754	-.35234
A8	.22953	.59249	.15480	.63169	.09549	-.19929	.02444	.12627	-.37351	.11447
A13	-.03134	.27307	-.48393	.13141	-.18746	-.25854	.29754	.08267	.65995	.21475
A14	.00346	-.22652	-.27634	.27205	.52932	.41834	-.14938	.42300	.01117	-.31192
A18	.10446	-.15533	.31740	.55178	-.07813	.25475	-.05659	-.33494	.62860	-.37493

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUP MEANS (GROUP CENTROIDS)

GROUP	FUNC 1	FUNC 2	FUNC 3	FUNC 4	FUNC 5	FUNC 6	FUNC 7	FUNC 8	FUNC 9	FUNC 10
1	1.66102	.18548	-.03113	.01091	-.01870	.06246	.00547	.01235	.00657	-.00216
2	.17439	-.66409	-.10082	.08354	.34206	-.17820	-.02608	.05837	-.09222	.02314
3	-.28959	-.29481	-.03500	-.23705	.23027	-.05395	-.15516	-.10127	.12645	.00407
4	-.54341	-.48738	.45118	.62817	-.10576	.18183	.00461	.00477	.04433	.00451
5	-.53352	-.45906	-.43831	-.06392	-.43372	-.00300	-.23045	.03995	-.01904	-.00491
6	-.22352	.38214	-.05983	.22028	-.18326	-.48842	.13572	-.11626	.00143	.00073
7	-.56091	.41495	.36785	-.11742	.05148	.16479	-.16746	-.15348	-.09952	-.00705
8	-.83743	.78137	.33520	-.23315	-.07797	-.08606	-.06659	.15973	.02731	.01923
9	-1.24956	.67074	-.62310	.23842	.22197	.21469	.10638	.02641	.00023	-.00437
10	-.45046	-.36452	.23680	-.14230	.13429	-.13169	.08375	.09260	-.00592	-.04235
11	-.44474	-.47069	.02151	-.42358	-.17555	.19252	.31522	-.04990	-.00512	.01350

APPENDIX 11

NOTES AND FORMS USED IN THE ACCEPTABILITY STUDY.

1. Instructions to be explained verbally to each volunteer.

Thank you for volunteering. During this experiment you will be telling us how much you like the different drumsticks.

You will be comparing nine different drumsticks (three at a time). They will be served on a tray in individual containers, each marked with a three figure number (show demonstration tray).

So we know how much you like the drumsticks, we would like you to mark a form for us (pass form to judge). You can see that on the form there are scales of how much you like the samples. The left hand side represents like extremely and the right hand side represents dislike extremely. Taste each drumstick and mark the line at the point that best describes your opinion (give example). Label the mark with the number of the drumstick.

Take your time and if you wish, rinse your mouth with water between samples. When you have finished your first three drumsticks, we will give you a second three drumsticks, followed by another three. Finally, we would like you to mark all nine drumsticks on one line as shown.

One thing we would like you to remember, is that different people like different things. This means that there are no right or wrong answers. We are interested in finding out what you as an individual think of these samples.

2. <u>Questionnaire completed by volunteers for the acceptability trial.</u>

Please tick your answer in the box provided.

1. Sex
   - Male
   - Female

2. Age
   - less than 25
   - 25 - less than 50
   - 50 & above

3. Job title _____

4. Hours worked
   - less than 20
   - 20 - less than 35
   - 35 & above

5. How often do you eat in the staff dining area?
   - Several times a week
   - Several times a month
   - Several times a year
   - Never

6. How often do you eat chicken dishes?
   - Several times a week
   - Several times a month
   - Several times a year
   - Never

7. How often do you buy prepared foods from vending machines e.g. sandwiches, pies, meals?
   - Several times a week
   - Several times a month
   - Several times a year
   - Never

Please hand this completed questionnaire to an instructor on the day of tasting (May 14th 1985)

Thank you for your help and cooperation.

Instructor: Volunteer number:

3. Scoring form used in the consumer trial.

In front of you are three drumsticks. Taste each one and mark the line (scale of liking) at the point representing your opinion. Label your mark with the number of the drumstick.

Like extremely — Dislike extremely

1ST 3

Repeat with next three drumsticks.

Like extremely — Dislike extremely

2ND 3

Repeat with next three drumsticks.

Like extremely — Dislike extremely

3RD 3

Finally, we would like you to mark all 9 drumsticks on one scale.

Like extremely — Dislike extremely

ALL 9

THANK YOU FOR YOUR HELP AND COOPERATION

VOLUNTEER NO:

INSTRUCTOR NAME:

APPENDIX 12

THE MULTIPLE REGRESSION SOLUTIONS REQUIRED TO CONSTRUCT THE ANALYSES OF COVARIANCE

Summary of specified models:

1. Dependent variable; Mean acceptability scores for the Barclays subjects (samples scored in groups of three)
   Independent variables; packaging (MAP, vacuum packaging and cling wrapping)*, storage life,
   interaction: Vacuum X storage life (SP1)
   MAP x storage life (SP2)
   Cling x storage life (SP3)

2. Dependent variable; Mean acceptability scores for the Barclays subjects (samples scored in one group of 9)
   Independent variables; packaging (MAP, vacuum packaging and cling wrapping), storage life,
   interaction: Vacuum X storage life (SP1)
   MAP x storage life (SP2)
   Cling x storage life (SP3)

3. Dependent variable; Mean acceptability scores for the Barclays subjects (samples scored in groups of three)
   Independent variables; storage life

4. Dependent variable; Mean acceptability scores for the Barclays subjects (samples scored in one group of nine)
   Independent variables; storage life

5. Dependent variable; Mean acceptability scores for the hospital subjects (samples scored in groups of three)
   Independent variables; packaging (MAP, vacuum packaging and cling wrapping), storage life,
   interaction: Vacuum X storage life (SP1)
   MAP x storage life (SP2)
   Cling x storage life (SP3)

6. Dependent variable; Mean acceptability scores for the hospital subjects (samples scored in one group of nine)
   Independent variables; packaging (MAP, vacuum packaging and cling wrapping), storage life,
   interaction: Vacuum X storage life (SP1)
   MAP x storage life (SP2)
   Cling x storage life (SP3)

7. Dependent variable; Mean acceptability scores for the hospital subjects (samples scored in groups of three)
   Independent variables; storage life

8. Dependent variable; Mean acceptability scores for the hospital subjects (samples scored in one group of nine)
   Independent variables; storage life

*: MAP: P1, Vacuum packaging: P2, Cling wrapping: P3

Model 1; Barclays subjects (samples scored in threes)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	6.	11.96482	1.99414	27.83976
RESIDUAL	2.	.14300	.07150	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
P1	.8464870	.34403	.50122	2.852
P2	1.771351	.71992	.50122	12.490
P3	2.306668	.82679	.76674	9.050
STORAGE	.2702636E-03	.00078	.05334	.000
SP3	.2730630	.56347	.13707	3.969
SP1	.2020270	.66762	.07614	7.040
(CONSTANT)	4.929999			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
SP2	999999.99999	99999.99999	-.00000	99999.999

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
P1	Vacuum	.07045	.00496	.00496	.07045	.8464870	.34403
P2	MAP	.27889	.07778	.07282	-.26892	1.771351	.71992
P3	Cling	.93651	.87705	.79927	.73530	2.306668	.82579
STORAGE		.96775	.93653	.05948	.47540	.2702636E-03	.00078
SP3	Cling x Storage	.97294	.94661	.01008	.75171	.2730630	.56347
SP1	Vacuum*Storage	.99408	.98819	.04158	.18825	.2020270	.66762
(CONSTANT)						4.929999	

Model 2; Barclays subjects (samples scored in one group of 9)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	6.	18.77406	3.12901	34.72278
RESIDUAL	2.	.18023	.09011	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
P1	1.835675	.59629	.56269	10.643
P2	3.072431	.99803	.56269	29.815
P3	2.993333	.85752	.84078	12.093
STORAGE	-.1035134	-.23882	.06044	2.933
SP3	.4501801	.74246	.15348	8.559
SP1	.2536436	.66993	.03548	8.805
(CONSTANT)	4.490000			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
SP2	999999.99999	99999.99999	-.00000	99999.999

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
P1	Vacuum	.04764	.00227	.00227	.04764	1.835675	.59629
P2	MAP	.27239	.07419	.07192	-.25608	3.072431	.99803
P3	Cling	.95848	.91868	.84449	.75916	2.993333	.85752
STORAGE		.96223	.92588	.00720	.36522	-.1035134	-.23882
SP3	Cling x Storage	.97398	.94863	.02275	.77518	.4501801	.74246
SP1	VacuumxStorage	.99523	.99049	.04186	.11694	.2536436	.66993
(CONSTANT)						4.490000	

Model 3; Barclays subjects (samples scored in threes)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	1.	2.73644	2.73644	2.04400
RESIDUAL	7.	9.37138	1.33877	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
STORAGE	.1646916	.47540	.11519	2.044
(CONSTANT)	6.137995			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
STORAGE	.47540	.22601	.22601	.47540	.1646916	.47540
(CONSTANT)					6.137995	

Model 4; Barclays subjects (samples scored in one group of 9)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	1.	2.52829	2.52829	1.07764
RESIDUAL	7.	16.42600	2.34657	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
STORAGE	.1583040	.36522	.15251	1.077
(CONSTANT)	6.361475			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
STORAGE	.36522	.13339	.13339	.36522	.1583040	.36522
(CONSTANT)					6.361475	

Model 5; hospital subjects (samples scored in threes)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	6.	5.10356	.85060	2.67017
RESIDUAL	2.	.63711	.31855	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
P1	1.602703	.94599	1.05794	2.295
P2	3.090000	1.82386	1.05794	8.531
P3	.3933315	.46502	1.61840	.305
STORAGE	-.1750000	-.73363	.11364	2.371
SP3	.4216669	1.26365	.28932	2.124
SP1	.2455405	1.17840	.16071	2.334
(CONSTANT)	5.030000			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
SP2	999999.99999	99999.99999	-.00000	99999.999

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
P1	Vacuum	.27545	.07587	.07587	.27545	1.602703	.94599
P2	MAP	.31693	.10044	.02457	-.00197	3.090000	1.82386
P3	Cling	.82967	.68835	.58791	.29523	.3933315	.46502
STORAGE		.83335	.69531	.00696	.42305	-.1750000	-.73363
SP3	Cling x Storage	.87149	.75949	.06418	.34657	.4216669	1.26365
SP1	Vacuumxstorage	.94288	.88902	.12953	.31159	.2455405	1.17840
(CONSTANT)						5.030000	

Model 6; hospital subjects (samples scored in one group of 9)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	6.	13.51466	2.25244	3.09736
RESIDUAL	2.	1.45443	.72721	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
P1	3.274865	1.19705	1.59846	4.197
P2	4.689460	1.71412	1.59846	8.607
P3	.8033352	.25897	2.44526	.108
STORAGE	-.3131031	-.82585	.17170	3.432
SP3	.8347745	1.54921	.43713	3.647
SP1	.2910811	.86510	.24282	1.437
(CONSTANT)	4.669999			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F
SP2	999999.99999	99999.99999	-.00000	99999.999

SUMMARY TABLE

VARIABLE		MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
P1	Vacuum	.24978	.06239	.06239	.24978	3.274866	1.19705
P2	MAP	.25085	.06293	.00054	-.14499	4.689460	1.71412
P3	Clang	.80910	.65464	.59171	.42437	.8033352	.25397
STORAGE		.83795	.70216	.04752	.23877	-.3131031	-.82585
SP3	Clang x Storage	.91270	.83303	.13087	.43912	.8347745	1.54921
SP1	VacuumxStorage	.95018	.90284	.06981	.21029	.2910811	.86510
(CONSTANT)						4.669999	

A12.7

Model 7; hospital subjects (samples scored in threes)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	1.	1.02742	1.02742	1.52589.
RESIDUAL	7.	4.71327	.67332	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
STORAGE	.1009141	.42305	.03169	1.526
(CONSTANT)	6.272191			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
STORAGE	.42305	.17897	.17897	.42305	.1009141	.42305
(CONSTANT)					6.272191	

Model 8; hospital subjects (samples scored in one group of 9)

ANALYSIS OF VARIANCE	DF	SUM OF SQUARES	MEAN SQUARE	F
REGRESSION	1.	.85339	.85339	.42320
RESIDUAL	7.	14.11570	2.01653	

VARIABLES IN THE EQUATION

VARIABLE	B	BETA	STD ERROR B	F
STORAGE	.9197133E-01	.23877	.14138	.423
(CONSTANT)	6.729053			

VARIABLES NOT IN THE EQUATION

VARIABLE	BETA IN	PARTIAL	TOLERANCE	F

SUMMARY TABLE

VARIABLE	MULTIPLE R	R SQUARE	RSQ CHANGE	SIMPLE R	B	BETA
STORAGE	.23877	.05701	.05701	.23877	.9197136E-01	.23877
					6.729053	

APPENDIX 13

THE PLOTS OF INDIVIDUAL SUBJECT PREFERENCE VECTORS ON DISCRIMINANT FUNCTIONS ONE TO THREE

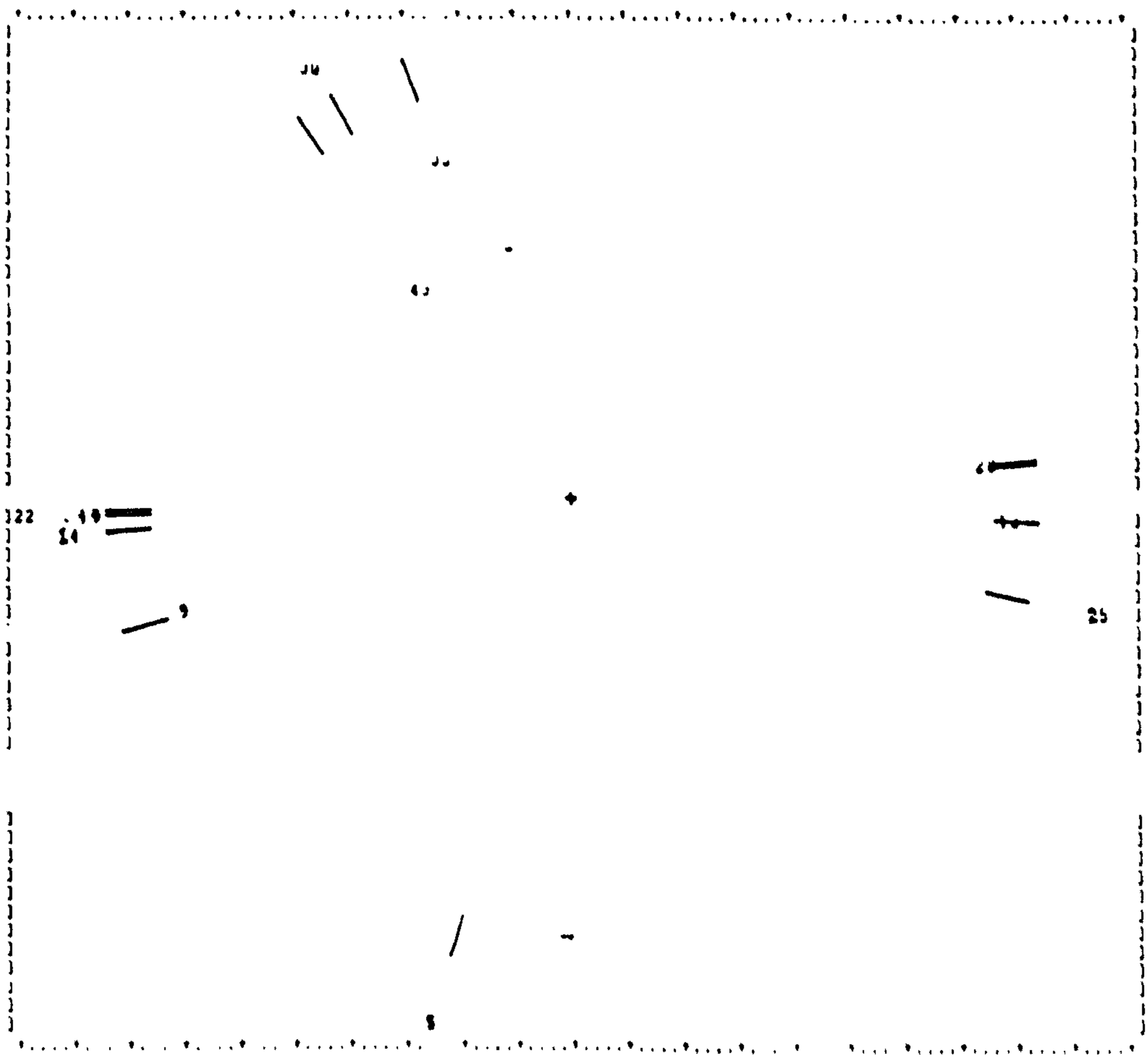
Graphs 1 to 8; discriminant function one and two

Graphs 9 to 16; discriminant function one and three

Graphs 17 to 24; discriminant function two and three

Discriminant functions one and two

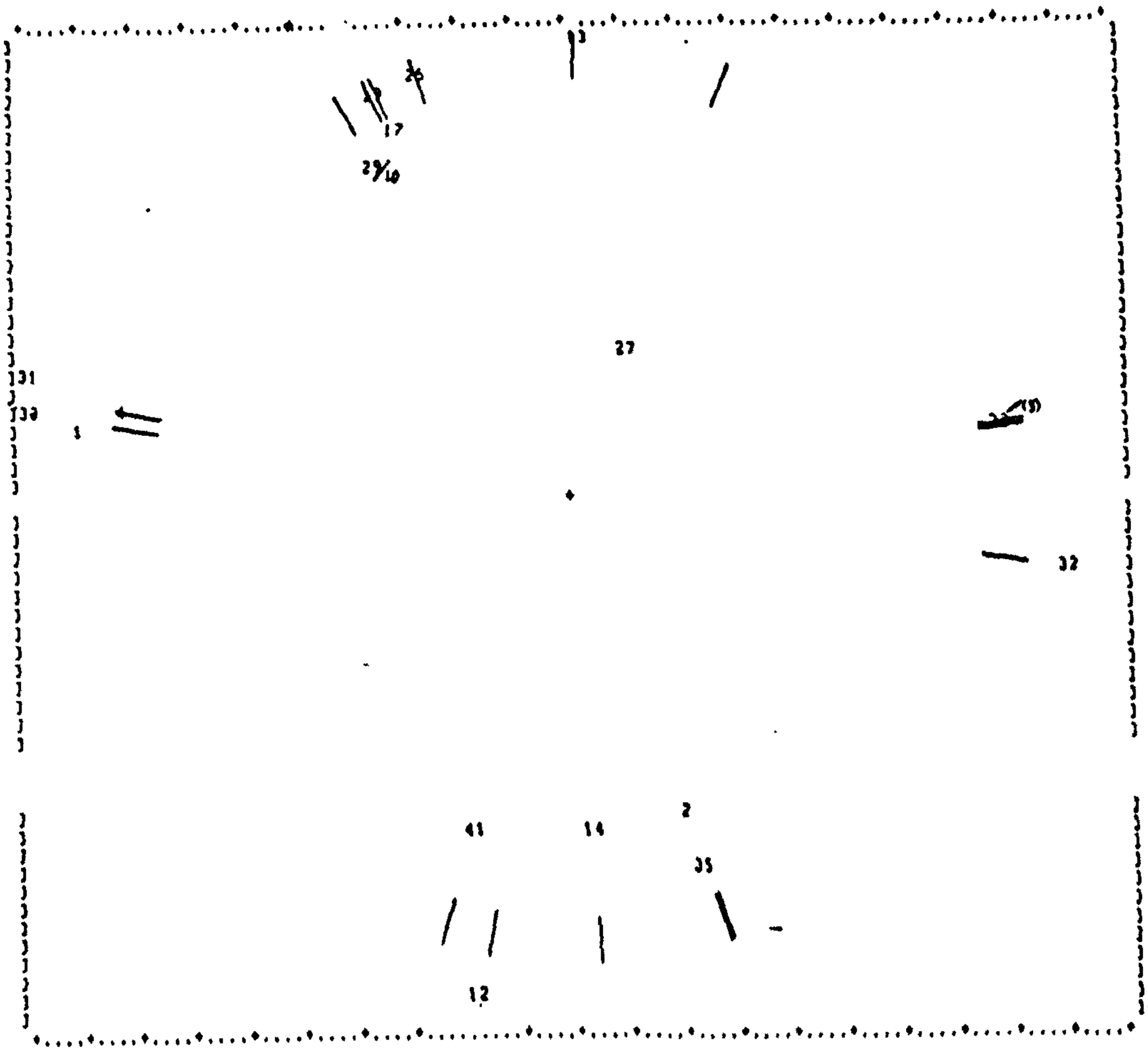
1. Barclays subjects (numbers 1 to 43),
samples scored in groups of 3.



F 13.2

Discriminant functions one and two

2. Barclays subjects (numbers 44 to 85),
samples scored in groups of 3.

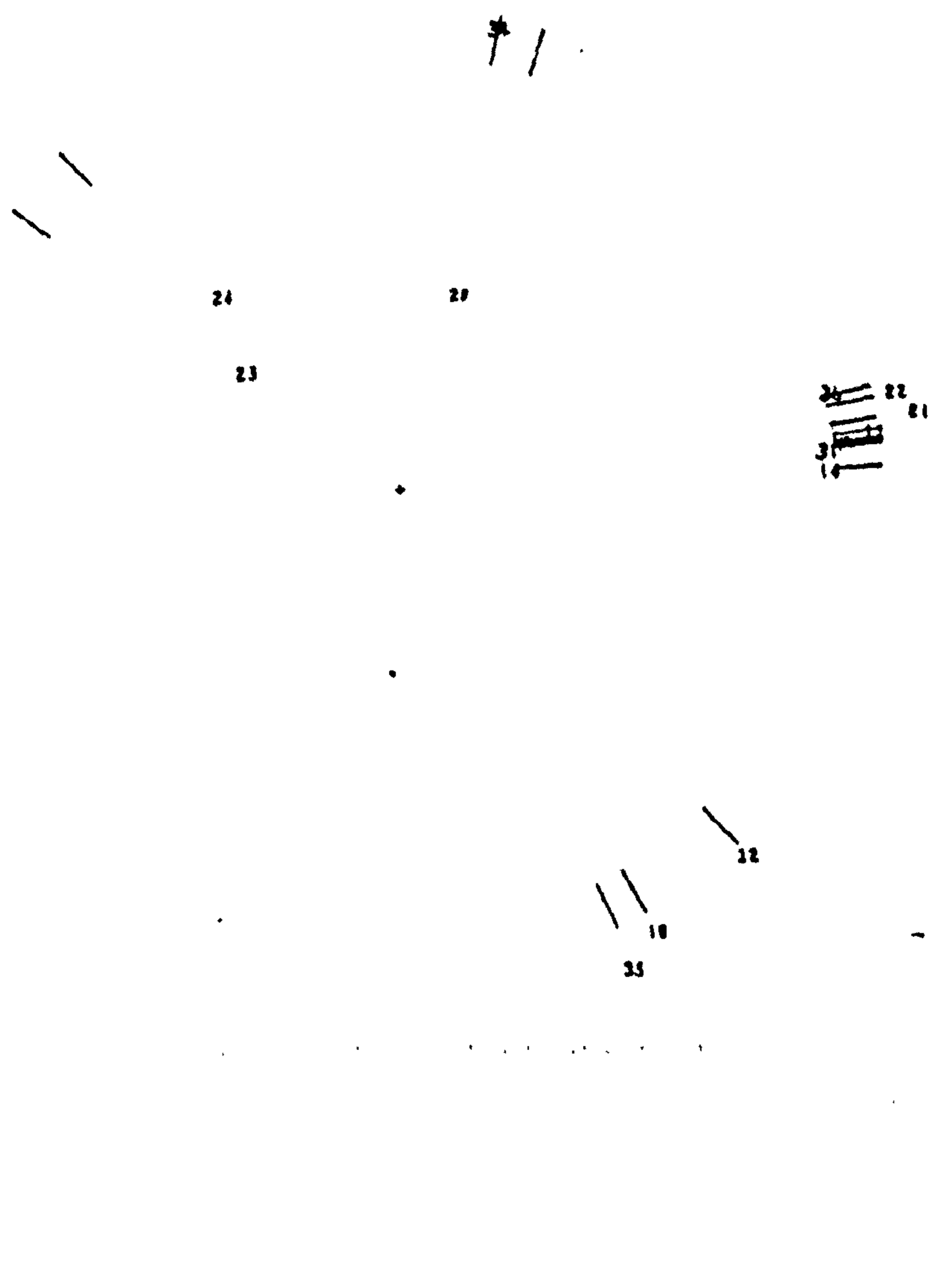


Discriminant functions one and two

3. Hospital subjects (numbers 1 to 33)
samples scored in groups of 3.

Discriminant functions one and two

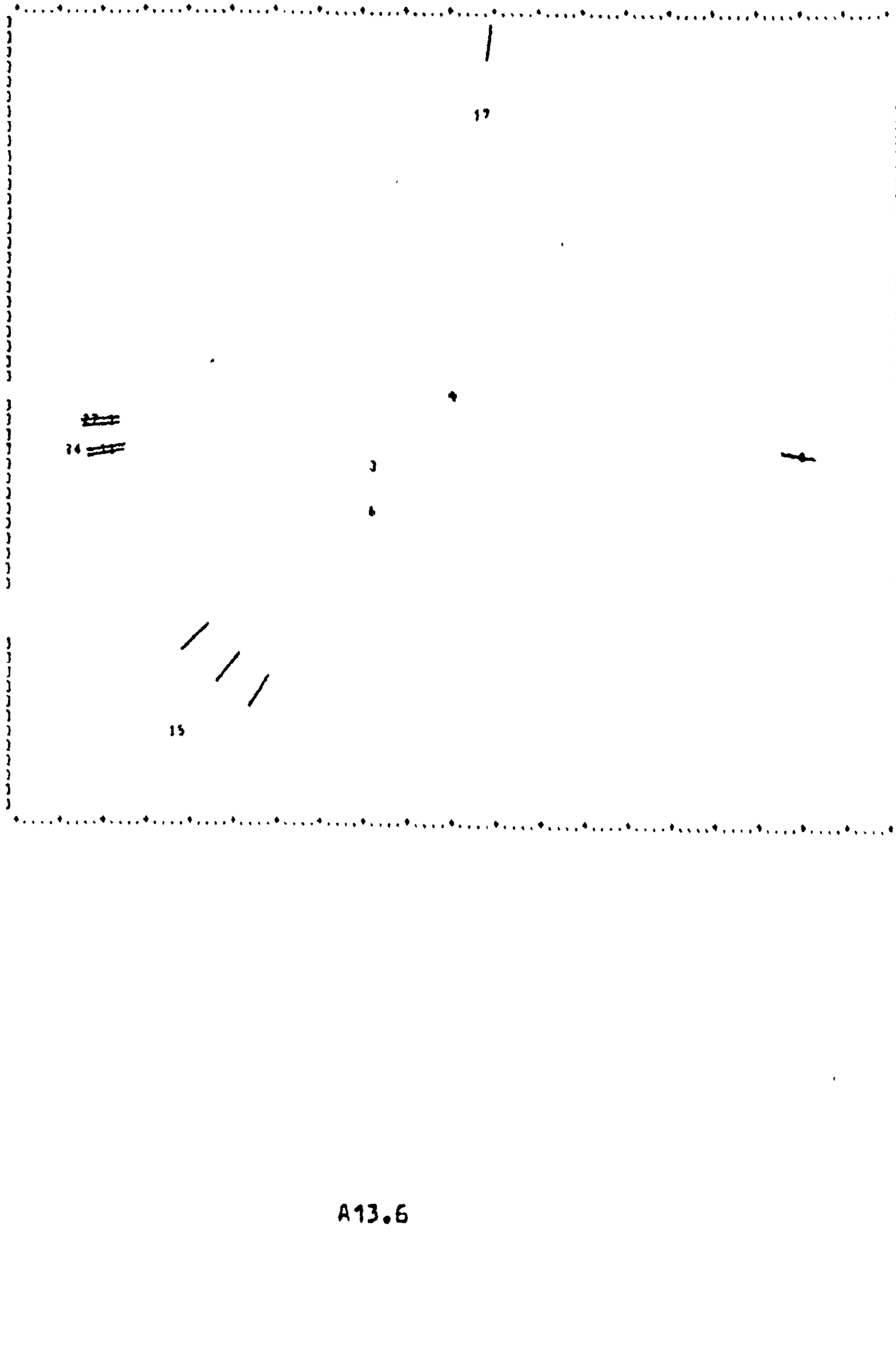
4. Hospital subjects (numbers 34 to 69), samples scored in groups of 3.



Discriminant functions one and two

5. Barclays subjects (numbers 1 to 36),

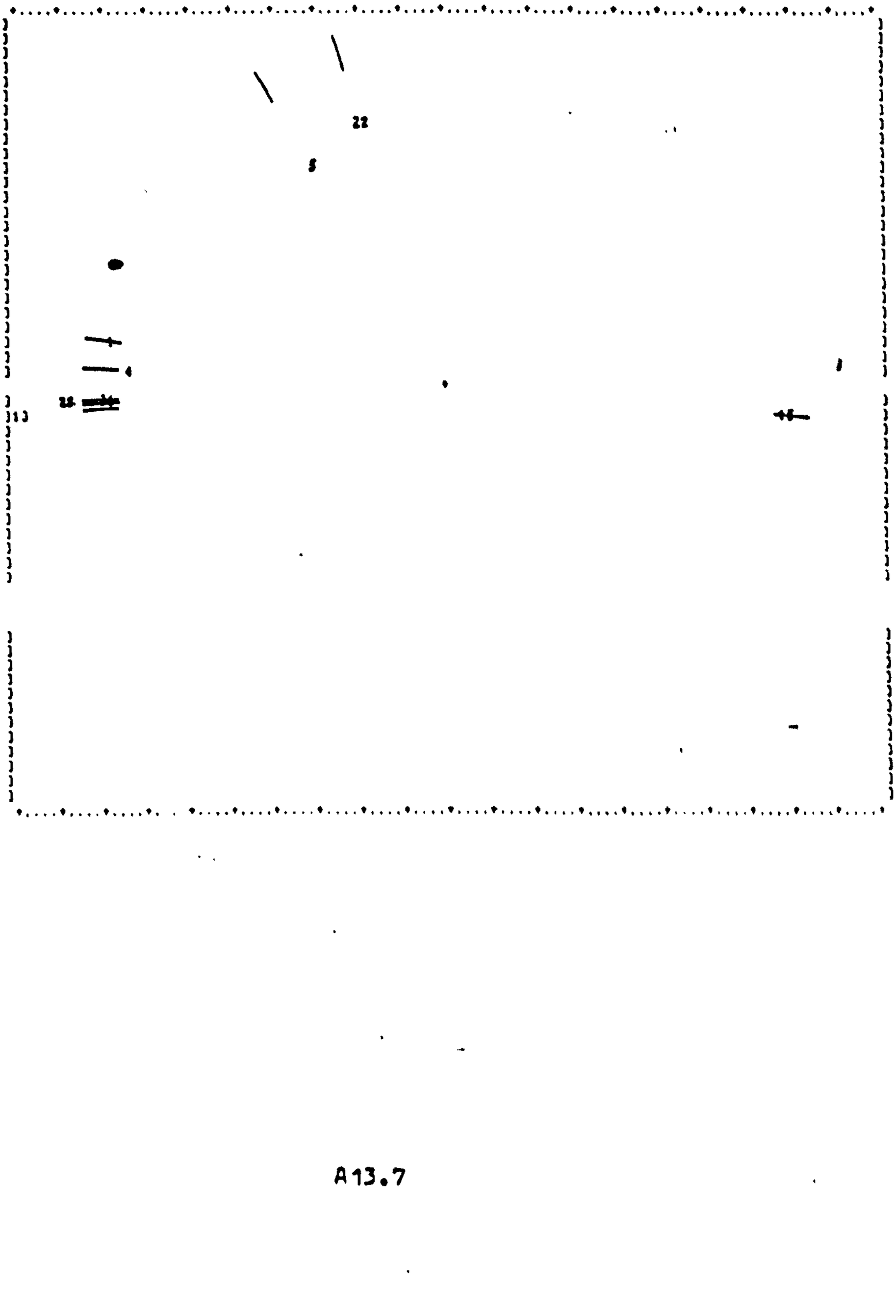
samples scored in one group of 9.



A13.6

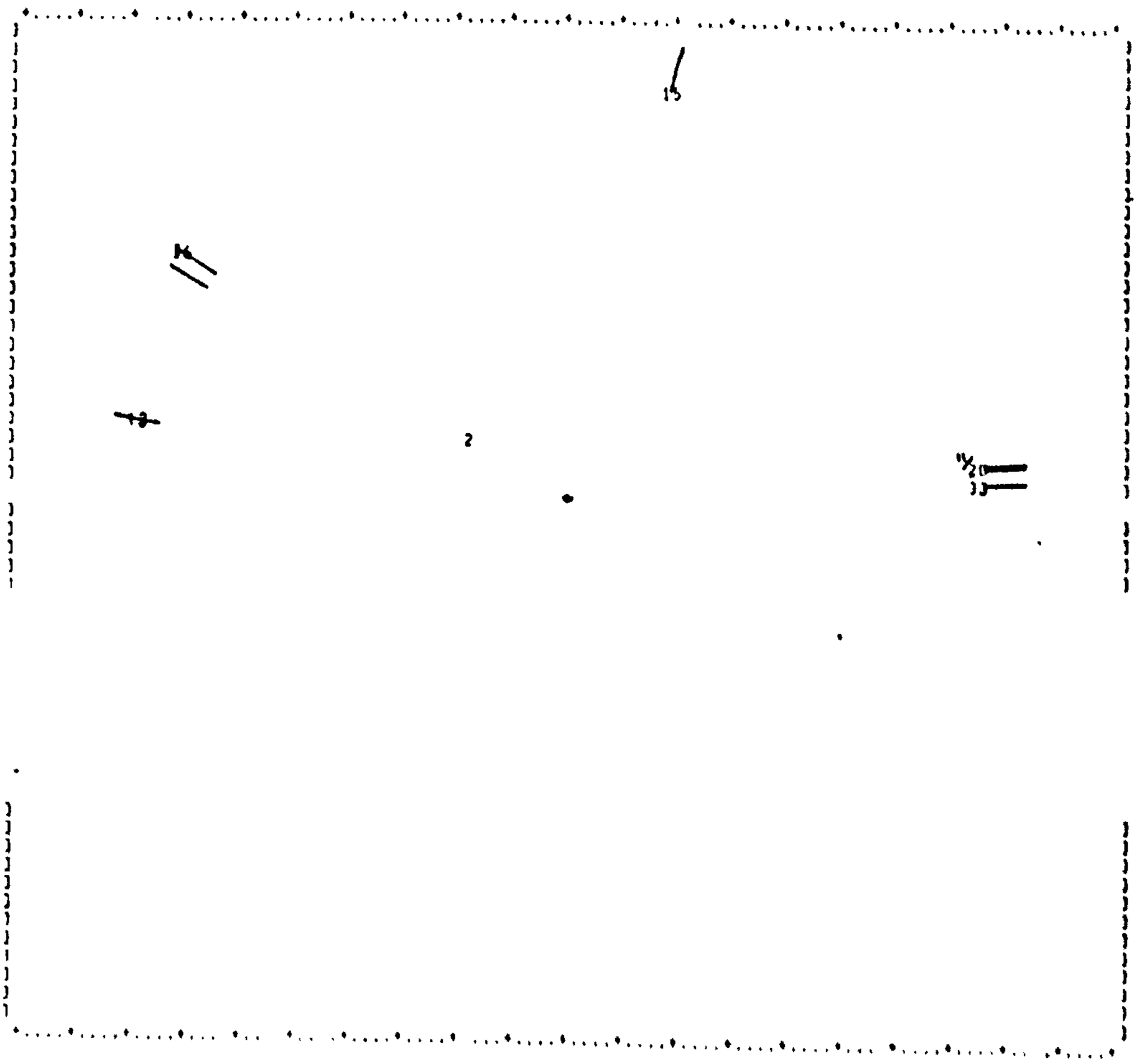
Discriminant functions one and two

6. Barclays subjects (numbers 37 to 72),
samples scored in one group of 9.



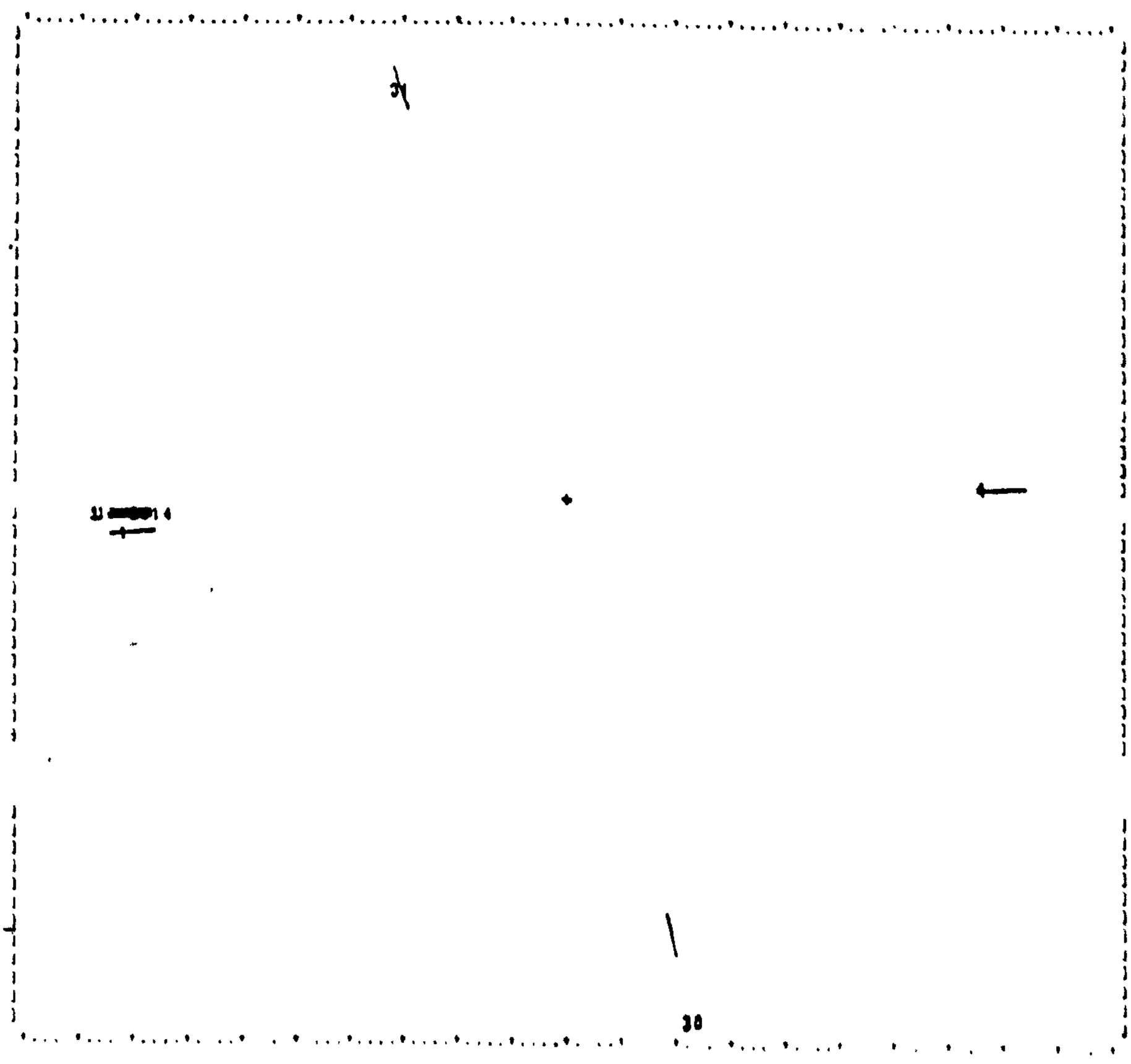
Discriminant functions one and two

7. Hospital subjects (numbers 1 to 33), samples scored in one group of 9.



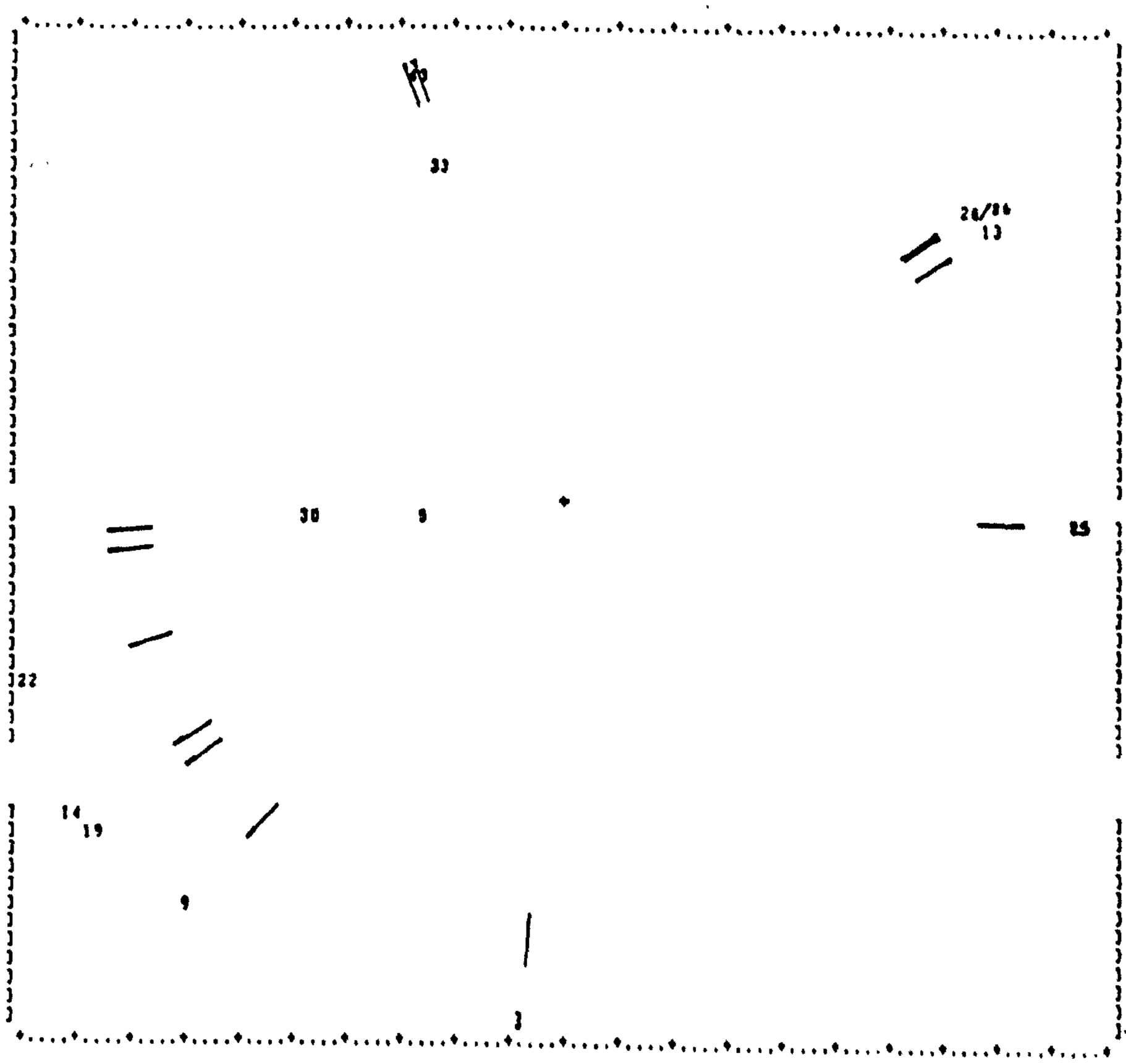
Discriminant functions one and two

8. Hospital subjects (numbers 34 to 67),
samples scored in one group of 9.



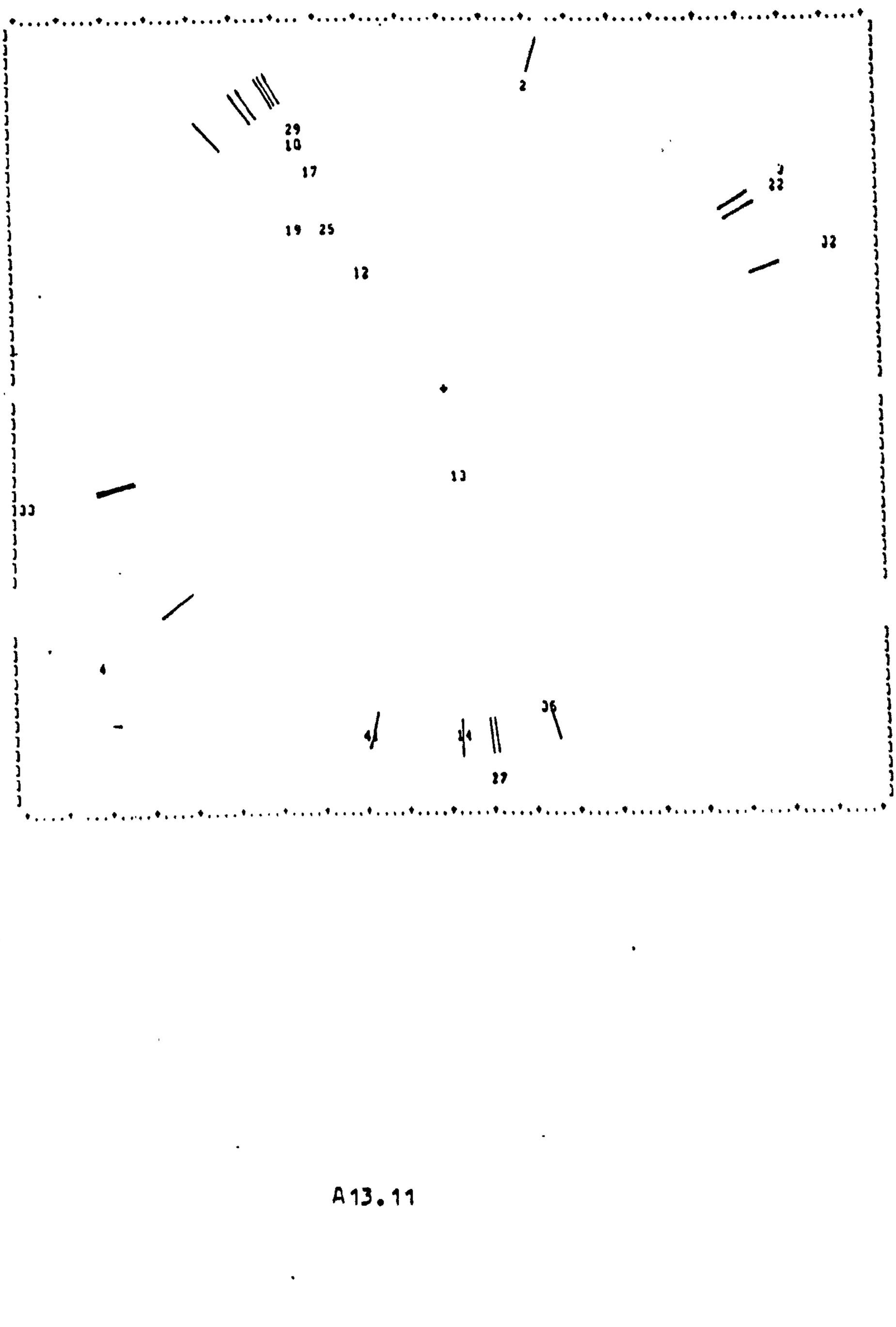
Discriminant functions one and three

1. Barclays subjects (numbers 1 to 43),
samples scored in groups of 3.



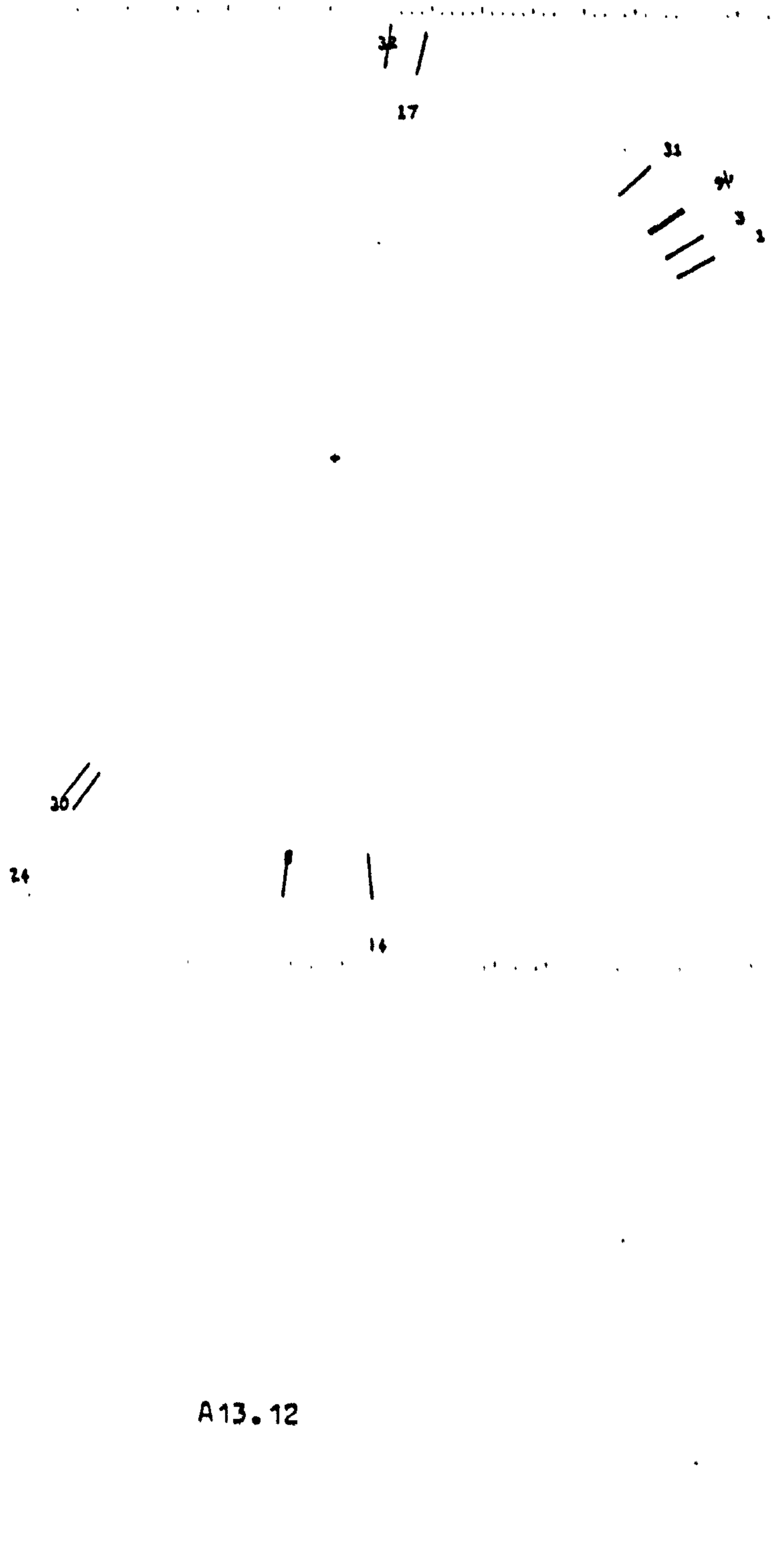
Discriminant functions one and three

2. Barclays subjects (numbers 44 to 85),
samples scored in groups of 3.



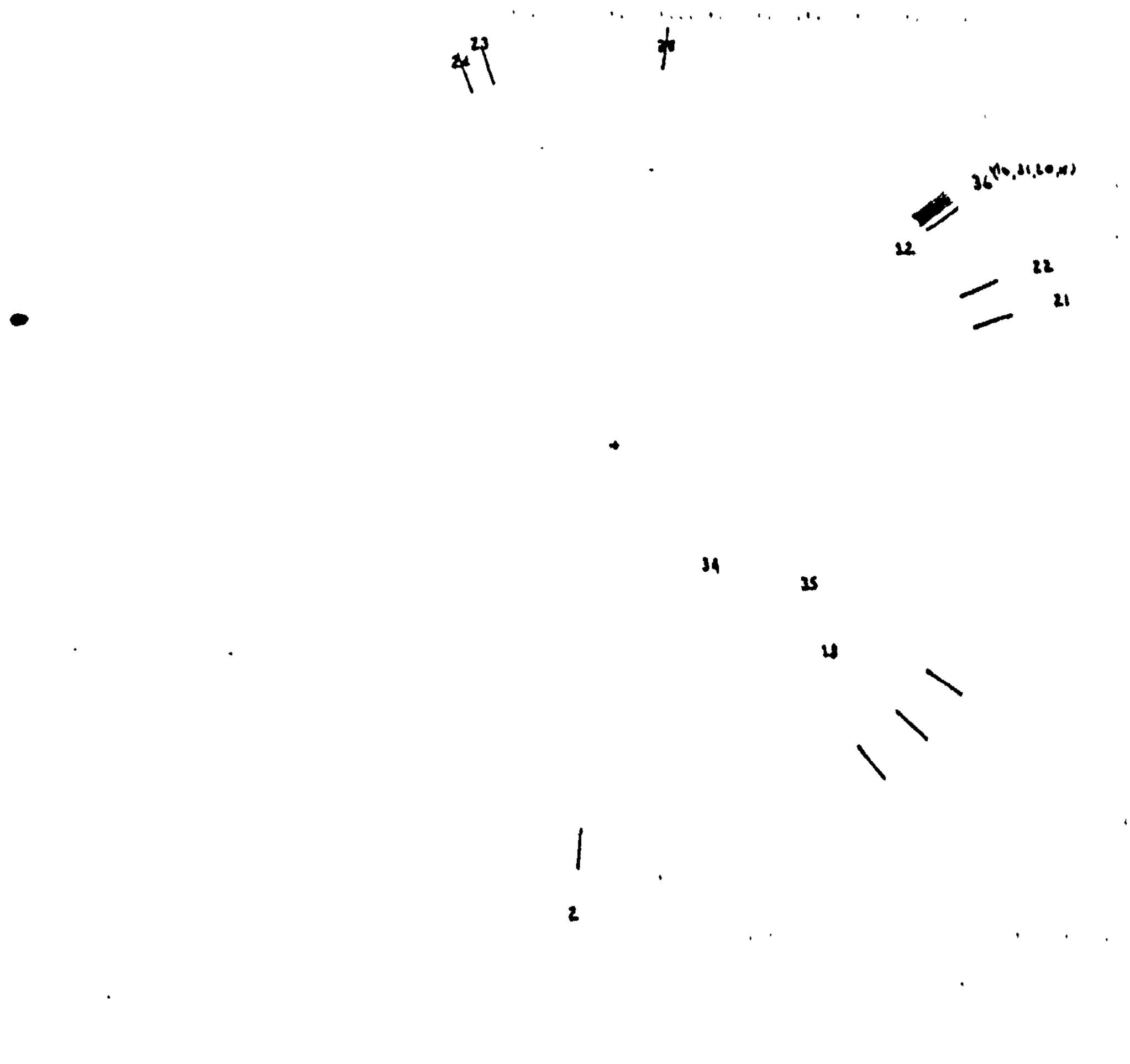
Discriminant functions one and three

3. Hospital subjects (numbers 1 to 33)
samples scored in groups of 3.



Discriminant functions one and three

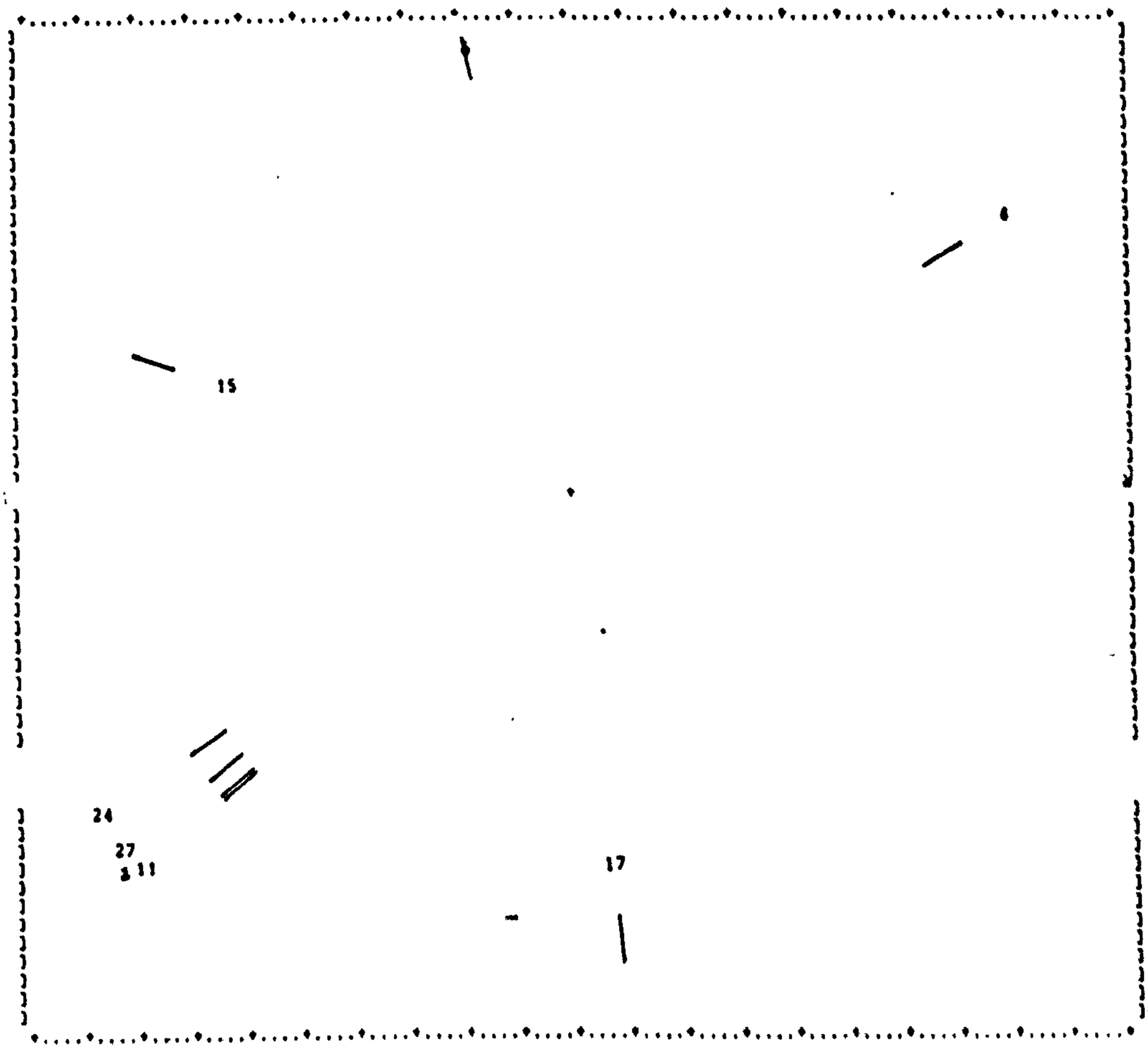
4. Hospital subjects (numbers 34 to 69),
samples scored in groups of 3.



Discriminant functions one and three

5. Barclays subjects (numbers 1 to 36),

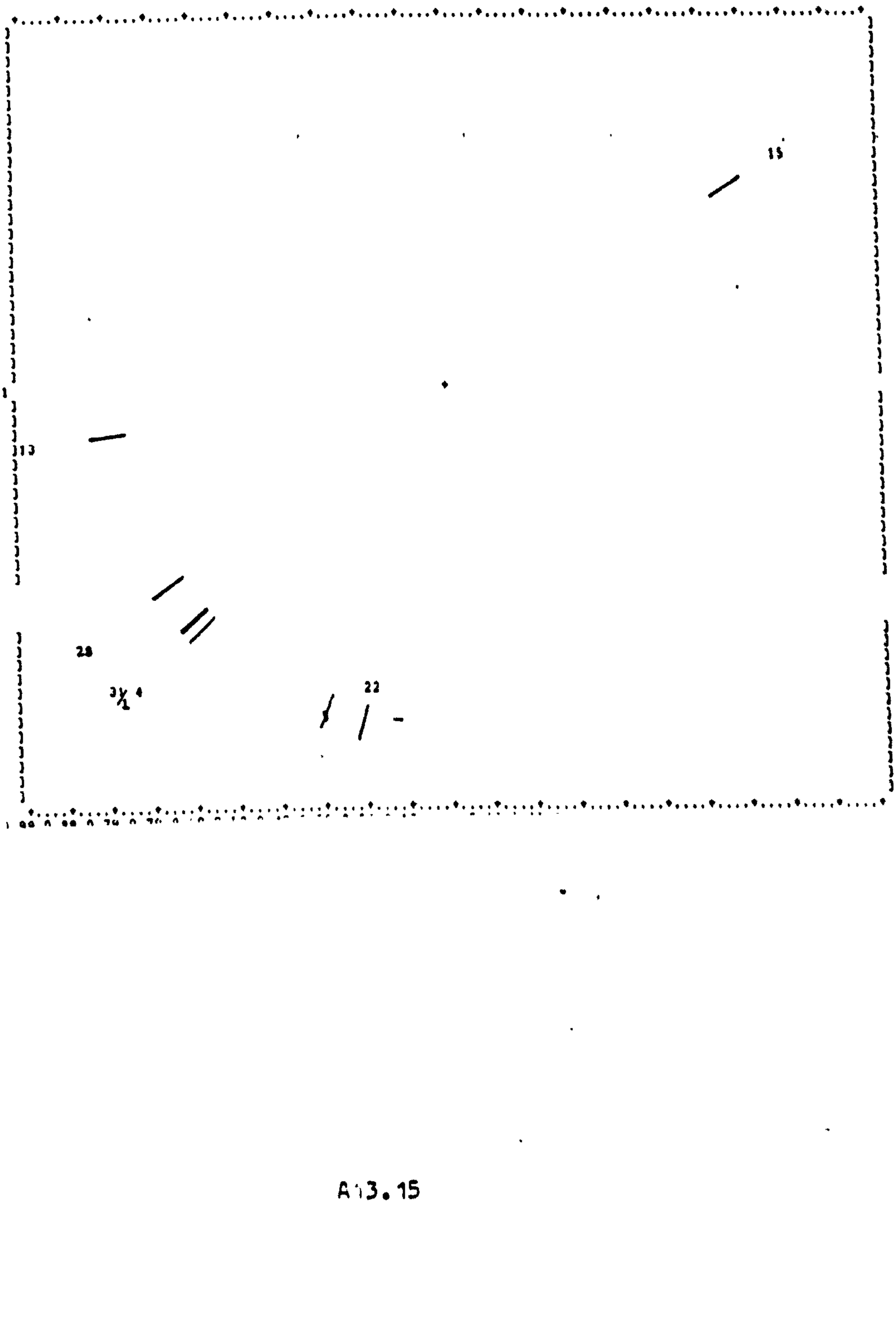
samples scored in one group of 9.



Discriminant functions one and three

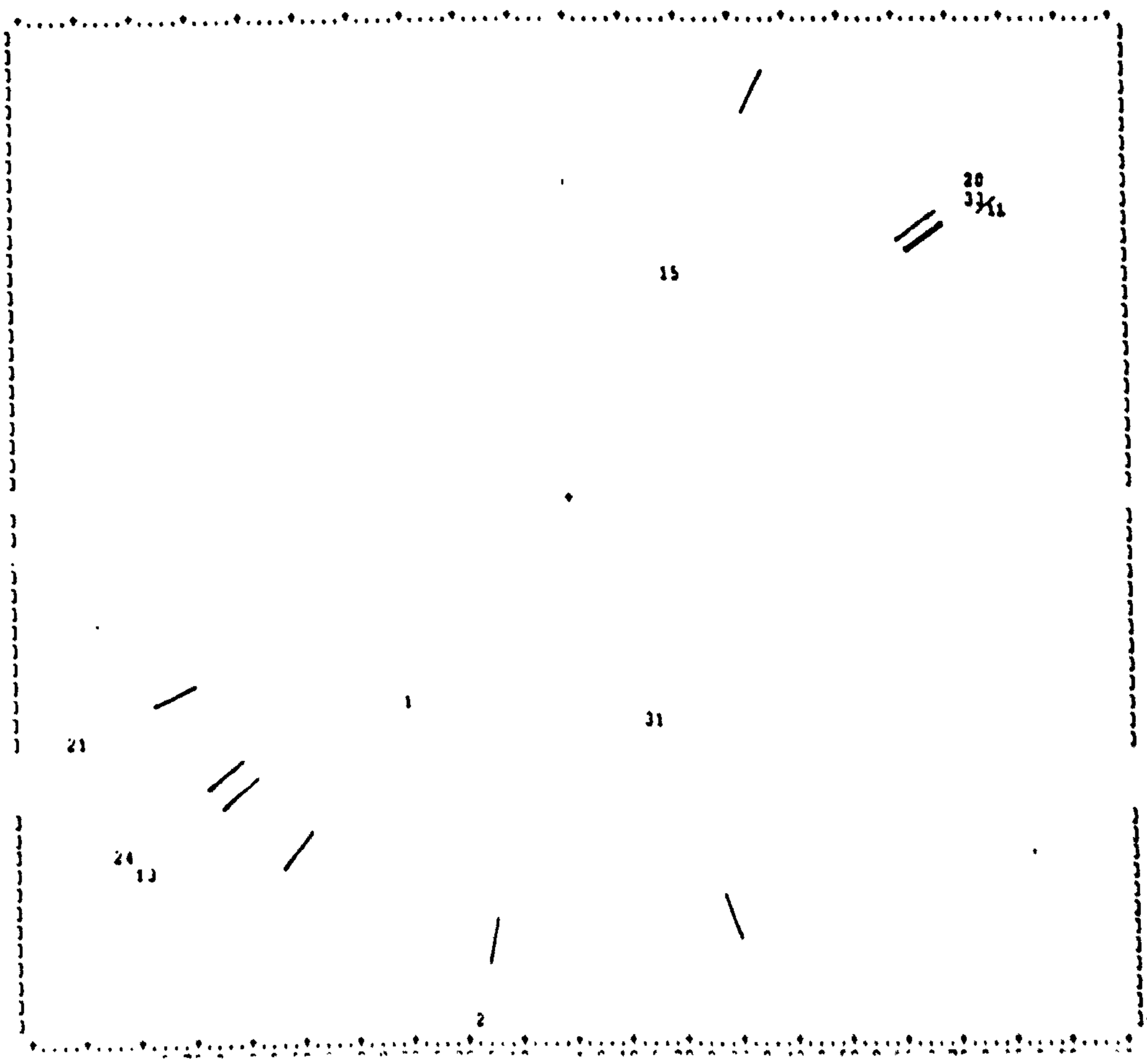
6. Barclays subjects (numbers 37 to 72),

samples scored in one group of 9.



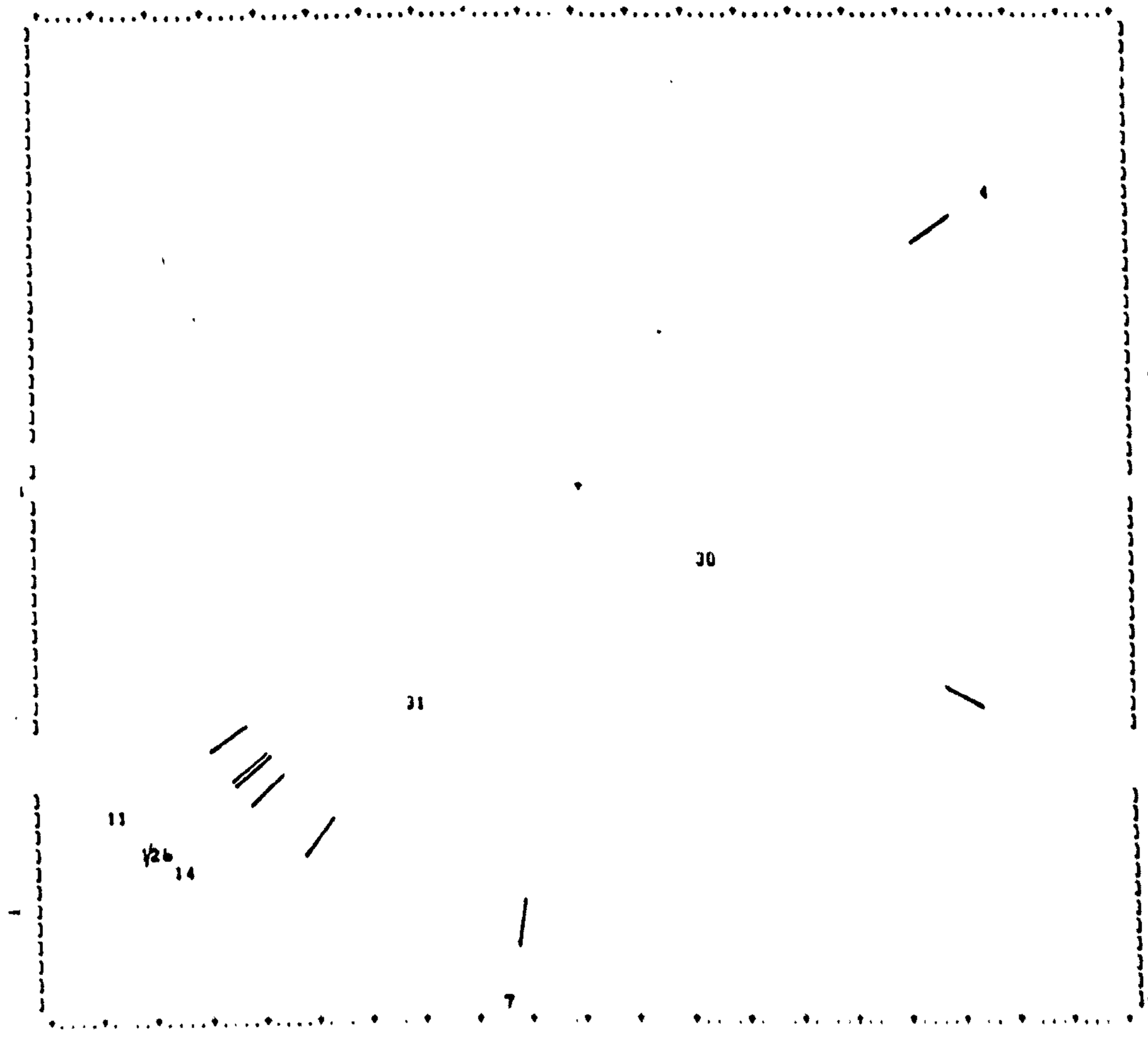
Discriminant functions one and three

7. Hospital subjects (numbers 1 to 33),
samples scored in one group of 9.



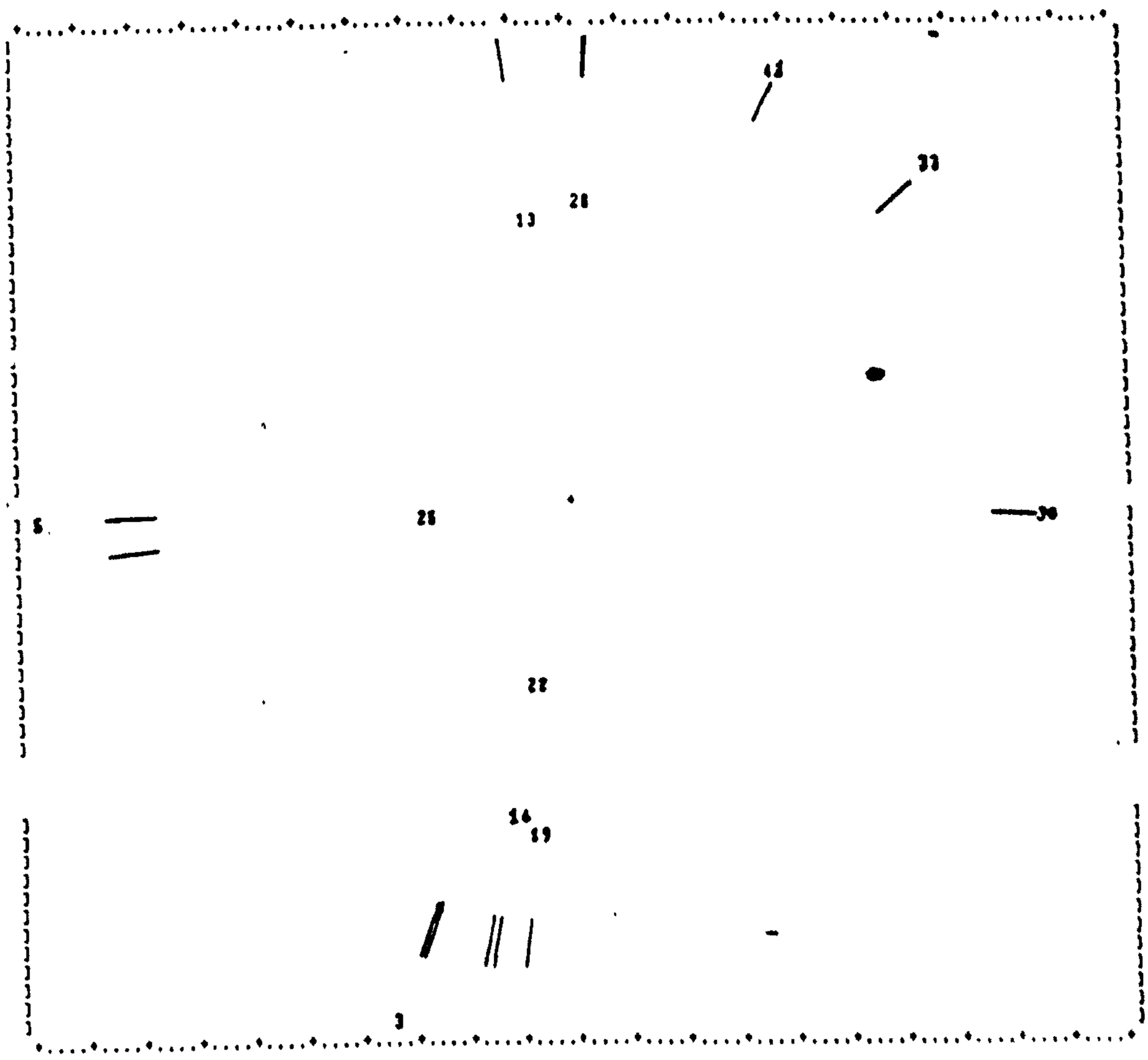
Discriminant functions one and three

8. Hospital subjects (numbers 34 to 67),
samples scored in one group of 9.



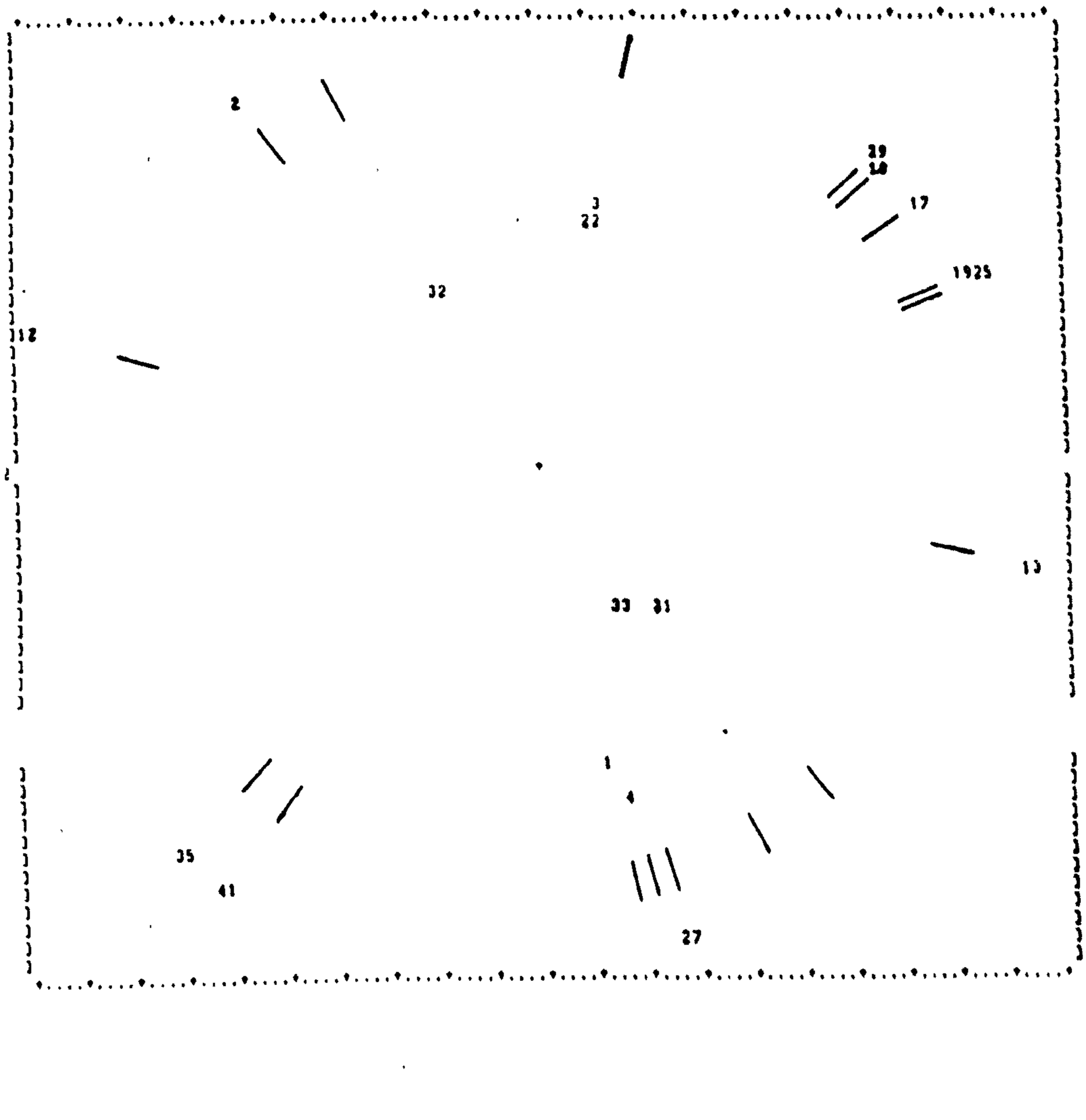
Discriminant functions two and three

1. Barclays subjects (numbers 1 to 43)
samples scored in groups of 3.



Discriminant functions two and three

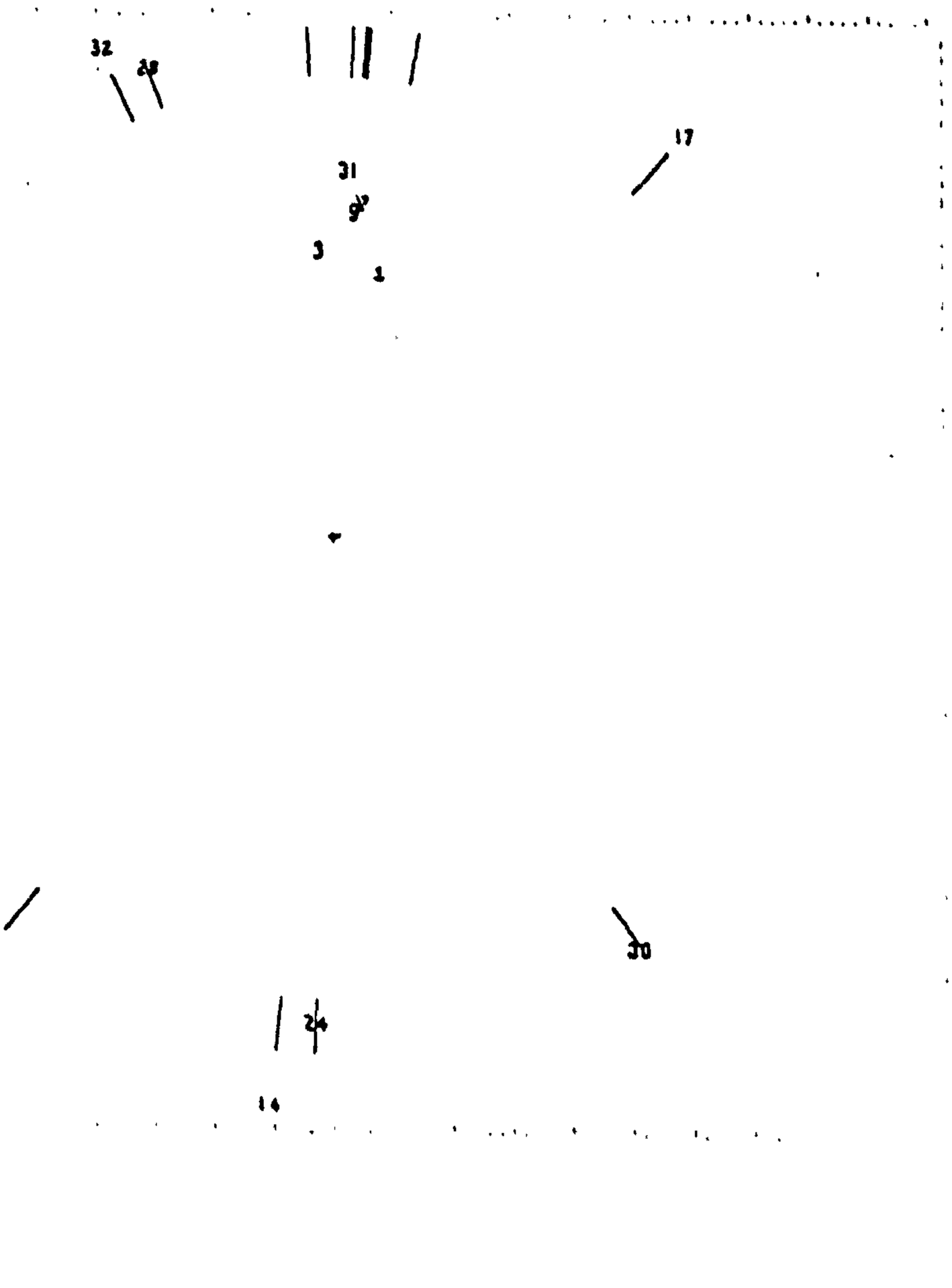
2. Barclays subjects (numbers (44 to 85),
samples scored in groups of 3.



Discriminant functions two and three

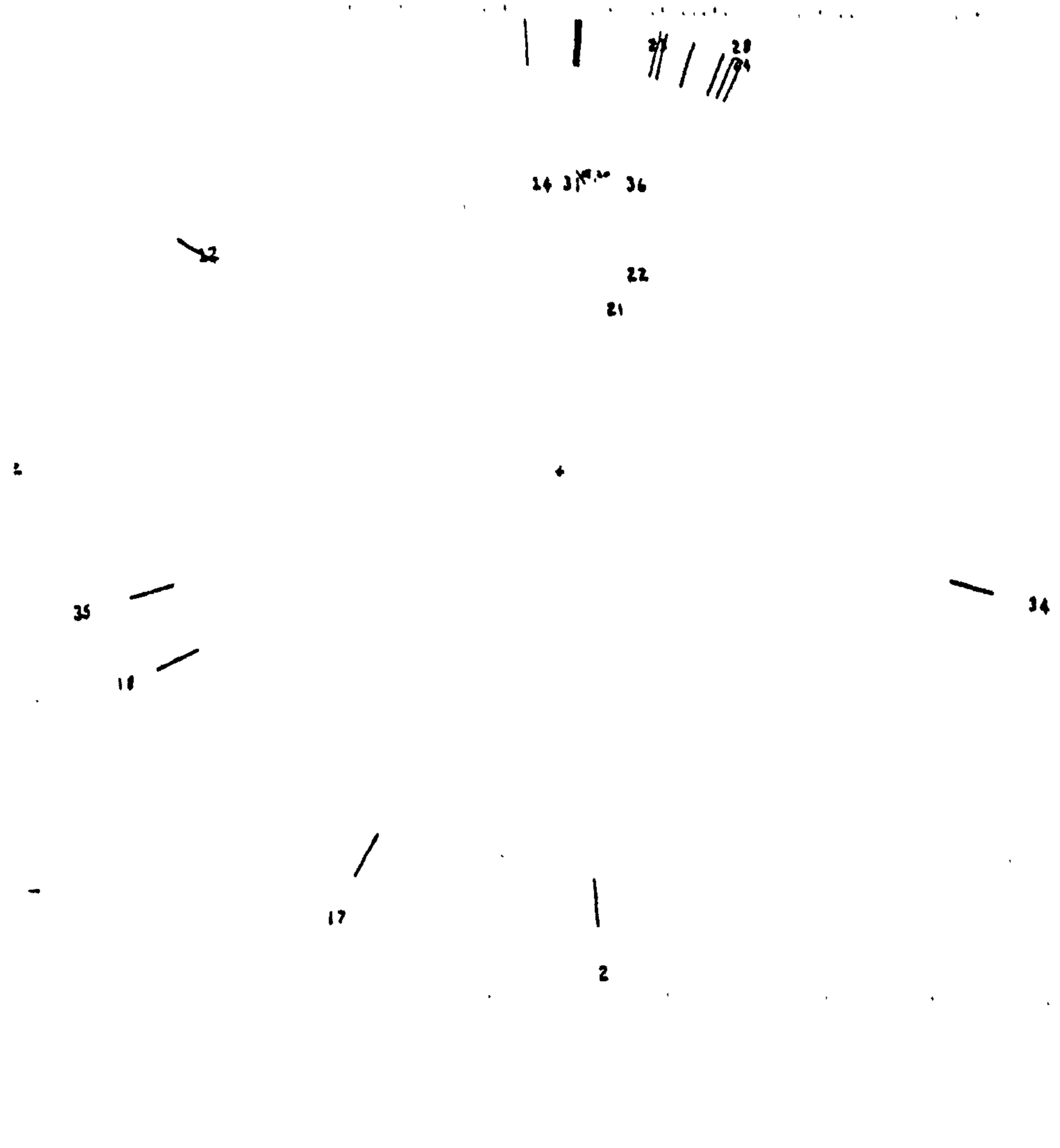
3. Hospital subjects (numbers 1 to 33)

samples scored in groups of 3.



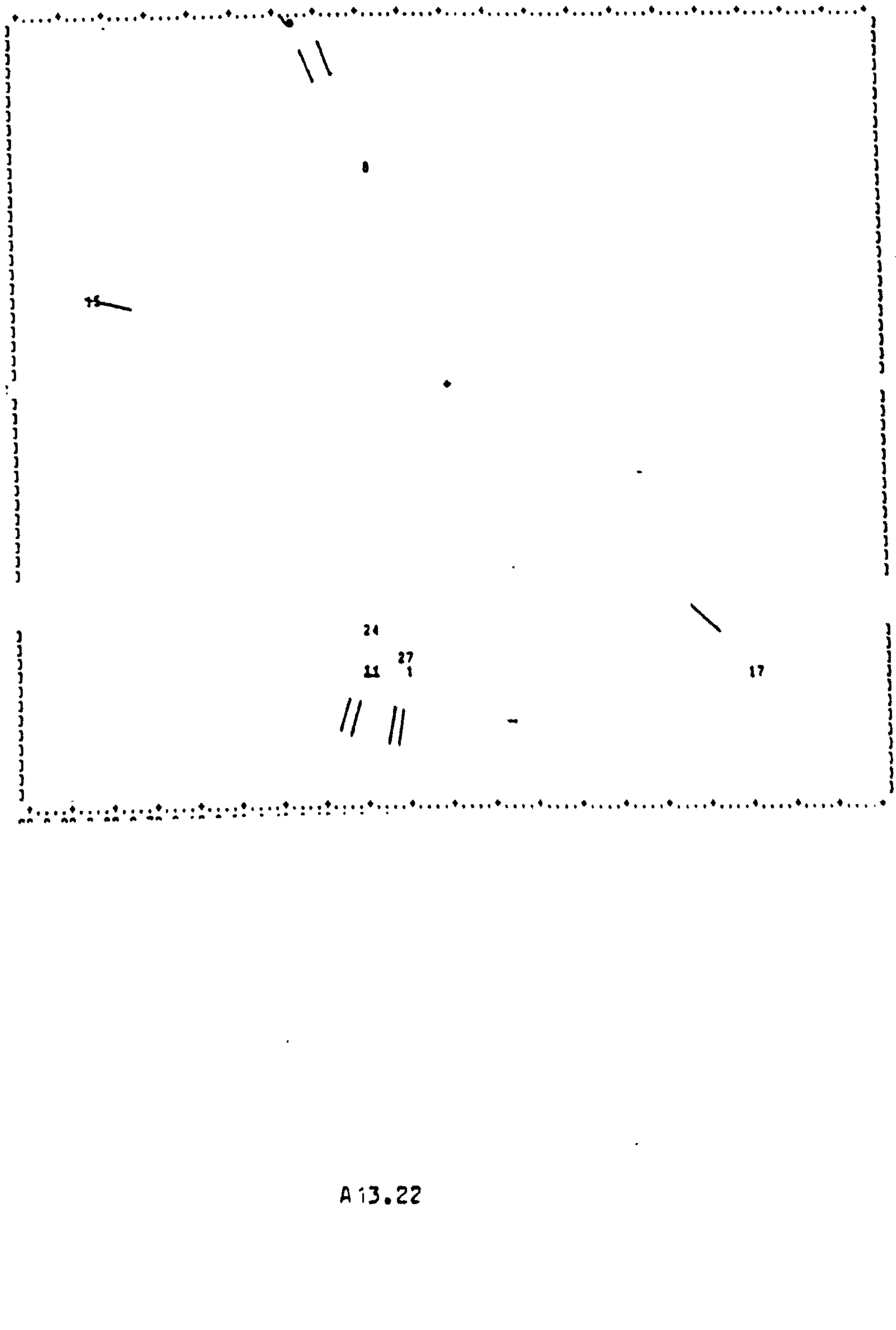
Discriminant functions two and three

4. Hospital subjects (numbers 34 to 69),
samples scored in groups of 3.



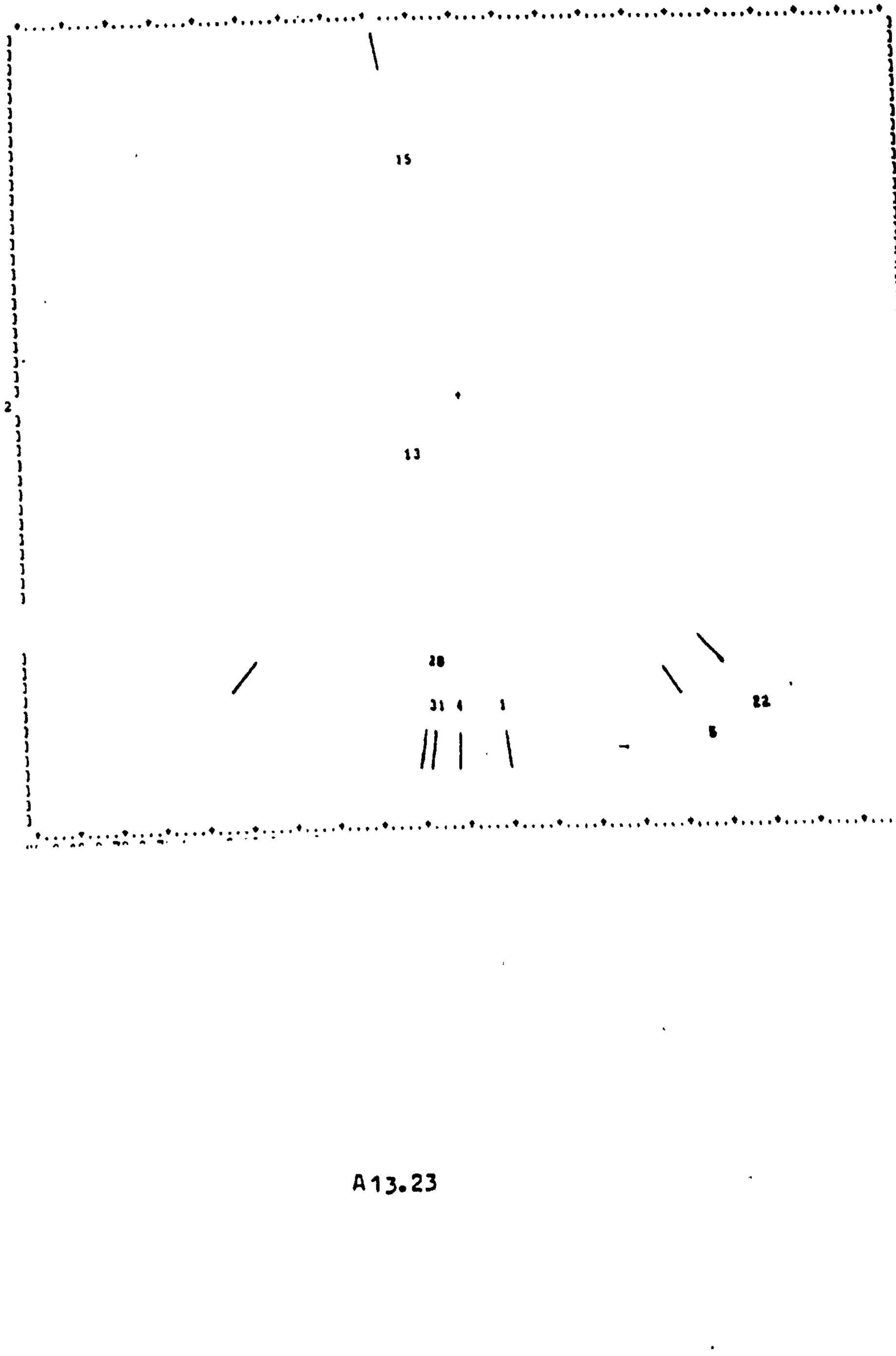
Discriminant functions two and three

5. Barclays subjects (numbers 1 to 36), samples scored in one group of 9.



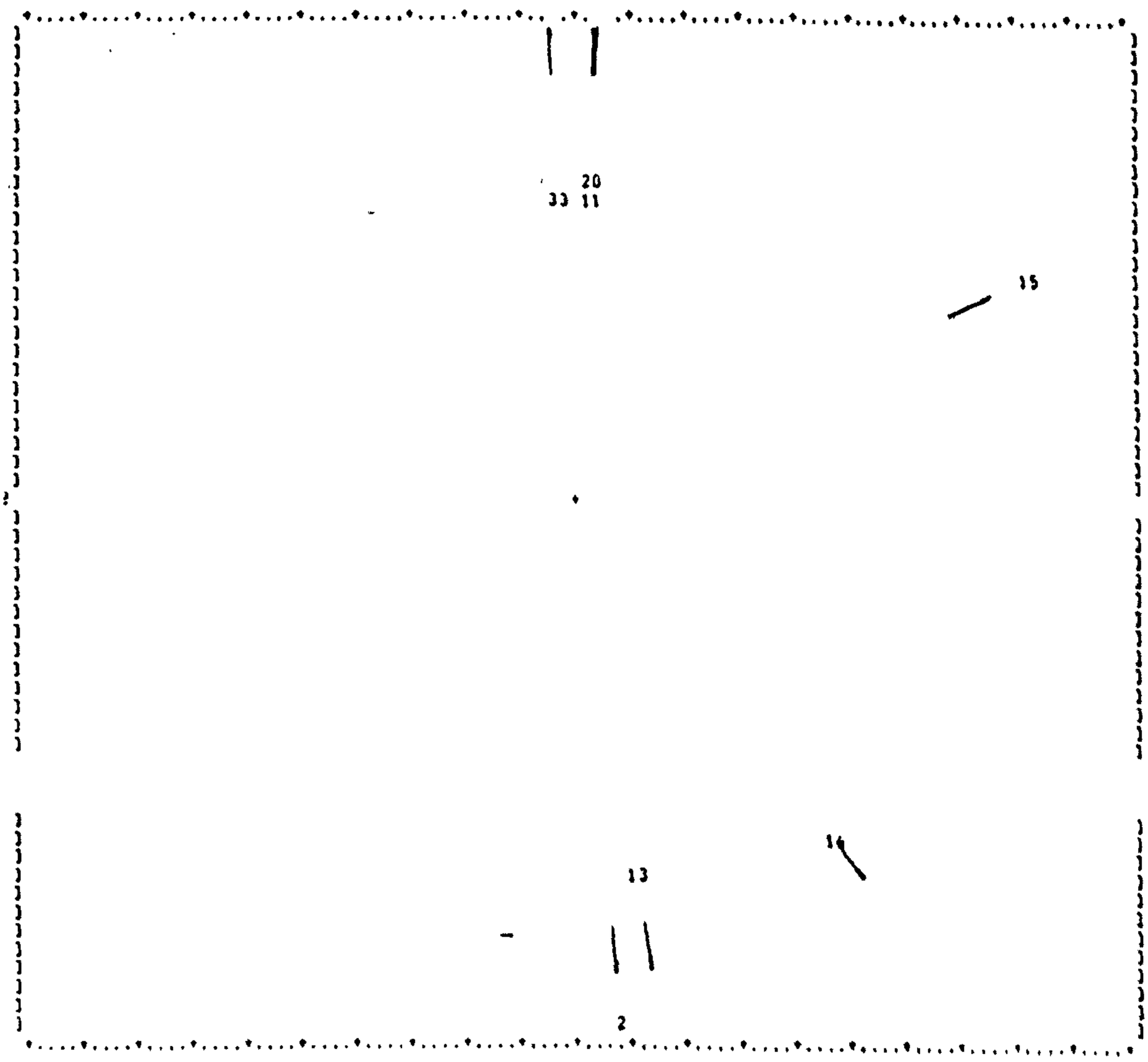
Discriminant functions two and three

6. Barclays subjects (numbers 37 to 72), samples scored in one group of 9.



Discriminant functions two and three

7. Hospital subjects (numbers 1 to 33), samples scored in one group of 9.



Discriminant functions two and three

8. Hospital subjects (numbers 34 to 67),

samples scored in one group of 9.