SOME ASPECTS OF THE PRODUCTION AND QUALITY IMPROVEMENT OF FERMENTED MILK/CEREAL MIXTURE (KISHK)

by

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ABSTRACT

Kishk is a very popular dried fermented milk/cereal mixture consumed in many countries of the world. The manufacture of Kishk is based on traditional methods, and may differ from one region to another. In the present study, the following aspects were investigated: First, standardising the production of laboratory-made Kishk; after using different ratios of wheat Burghol and yoghurt, a ratio of 1:4 was found to be suitable. Second, evaluating the compositional quality of Burghol made from different varieties of oats and barley, and the effect of these cereals on the overall characteristics of Kishk. Third, assessing the quality of Kishk using different cereals (porridge oats, oats flour, wheat flour, Burghol and Burghol flour), yoghurt, acidulant and/or 'milk'.

Burghols from different varieties of barley and oats were prepared in a similar manner to that for the production of wheat Burghol. The traditional cracking process was successful for barley and oats, but difficulties were experienced in the separation of husk from the oats product. The chemical composition of the parboiled 'cracked' cereals were compared with that of the original grains, and with wheat Burghol. In all, the proximate composition (*i.e.* fat, protein and ash) of the parboiled 'cracked' products were reduced compared to the original cereals. The overall fibre content of the 'cracked' barley was lower, whilst the starch, β-glucan and phytic acid contents were higher than the corresponding original grains. In comparison with original grains, the fibre content of the parboiled 'cracked' oats was also lower, whilst the starch and β-glucan was higher. The concentration of Cu, Ca, Zn and Mn contents was different between the cereal grains and 'cracked' products ($P < 0.05$).

Different Kishks were prepared by mixing 4 parts of low-fat yoghurt, D-glucono-δ-lactone (GDL) or 'milk', 0.75 - 1.00 g 100 g^{-1} salt and one part of Burghol (barley, oats or wheat), wheat Burghol flour, wheat flour, porridge oats or oats flour. Each mixture was kneaded

twice daily and fermented for six days at 20 - 25°C, and then shaped into nuggets and placed into stainless steel trays and dried at ~ 50°C for 8 - 10 h in a bakery oven. The dried Kishk was milled to a powder using a hammer mill with mesh size of 0.8 mm. Kishk made with 'milk' was produced in a similar manner described above, but without the addition of salt or using the secondary fermentation period. Kishks made with oats or wheat flours were thin in consistency after the secondary fermentation period, and, as a consequence, each mixture was first spread over the stainless steel tray, dried for a short duration to decrease the moisture content, then shaped into nuggets and dried.

The compositional quality of these Kishks varried depending on the type of cereal used, and the results could be summarised as follows:- First, oats (Burghol)-based Kishk had higher contents of fat, fibre, β-glucan, mono-unsaturated fatty acids contents and certain minerals; however, the starch and phytic acid contents of oats (Burghol)- and wheat (Burghols)-based Kishk were similar, but higher in barley (Burghol)-based Kishk. Second, the quality of Kishk made with different cereals (porridge oats, oats flour, Burghol, Burghol flour or wheat flour) using yoghurt, acidulant or 'milk' was influenced by the type of cereals and the 'dairy' base used. Wheat-based Kishk contained higher amounts of protein and carbohydrate, but was lower in fat, fibre, β-glucan, phytic acids contents and certain minerals compared to oats-based Kishk. Oats or wheat flour-based Kishk had higher contents of starch, but lower fibre, β-glucan and phytic acid contents. GDL-based Kishk had lower fat and starch contents compared to yoghurt-based or 'milk'-based Kishks due to the complex structure produced by the GDL. This resulted in the entrapment of the fat globules in the protein matrix, and starch complexes with lipids, protein and polyphenol. Third, all the yoghurt-based Kishk had higher levels of lactic acid, and the GDL-based products contained acetic and propionic acids, whilst the 'milk'-based Kishk contained higher levels of orotic acid.

In general, all the Kishks made with different cereal components or Burghols were produced under good hygienic and sanitary conditions. The microbiological quality was within an acceptable range. Wheat based-Kishks had an appreciable viable counts of starter organisms after the storage period (6 and 12 months) which may have contributed towards the safety of the product.

Sensory evaluation of these Kishks could be summarised as follow:- First, Kishks made with different cereal Burghols (oats, barley or wheat) were differentiated by the type of cereal used. Second, the flavour of Kishk made with different cereals (oats and wheat), yoghurt, GDL and 'milk' were different. Most of the odour, flavour, after-taste and mouth feel characters have differentiated the Kishk according to the type of 'dairy' base used. The perceived mouth feel characters (*chalky, sticky, slimy*) differentiated the Kishk according to the type and particle size of cereals (*e.g.* porridge oats, oats flour, wheat Burghol or wheat flour) used. Third, Kishk made with different wheat products (Burghol, Burghol flour or wheat flour) was also differentiated by the particle size. Fourth, wheat flour-based Kishk was perceived to have better mouth feel characters followed by Burghol flour- and Burghol-based Kishk.

Yoghurt/Burghol or wheat flour mixtures were studied during the secondary fermentation period (0, 48, 96 and 144 h), and the influence of particle size of the cereal was evident on the α-amylase and proteolytic activities. Burghol-based mixture had the highest α-amylase content/activity and wheat flour the lowest, whilst the non-protein nitrogen compounds content was higher in wheat flour- than the Burghol-based mixture after 144 h. The degradation of starch in all these mixtures was almost linear during the secondary fermentation period. This appeared to be influenced by the interactions between the starch and other components such as protein, lipids and polyphenols to make the starch resistant to enzymatic degradation. The release of enzyme inhibitors such as phytic acids during the secondary fermentation period may also have interfered in the recovery of the starch during analysis.

The microstructure of cereal (Burghol or wheat flour)/yoghurt or whey from yoghurt mixture suggest that physical change in starch granules occurred rather than degradation.

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ABBREVIATIONS

Acidulants	Yoghurt or direct acidified milk
ADPI	American Dairy Products Institute
AMF	Anhydrous milkfat
ANOVA	Analysis of variance
BSI	British Standards Institution
ca	Approximately
~	Approximately
cfu	Colony forming unit
CLSM	Confocal laser scanning microscopy
'Dairy' base	Yoghurt, direct acidified milk or reconstituted low fat milk
DMB	Dry matter basis
DVI	Direct to vat inoculation
GDL	D-glucono-δ-lactone
IDF	International Dairy Federation
'Milk'	Low fat reconstituted milk not fermented or chemically acidified
MPa	Mega Pascal
PC	Principal Component
PCA	Principal Component Analysis
SED	Standard error of difference of mean
SI	Statutory Instruments
SMP	Skimmed milk powder

CHAPTER ONE:

INTRODUCTION

CHAPTER ONE: INTRODUCTION

Food is necessary for survival, growth, physical ability and good health (Vieira, 1996). The first food that we eat are those which our ancestors ate, and these early eating habits remain with us for rest of our lives. New eating habits may be acquired depending on where we live (Baker *et al.*, 1988). For the majority of world's human population, cereal-based foods constitute the most important source of energy and other nutrients. In the poorest parts of the world, starchy foods, including cereals, may supply 70% of the total energy (Kent and Evers, 1994). However, the typical food consumed in "Western" countries is high in fat, refined carbohydrates (*e.g.* white flour and sugars) and low in fibre. There are strong links between such types of diet and coronary disease, obesity, bowl disorder and tooth decay (Gaman and Sherrington, 1990). It is now realised that modifying the diet may reduce the risk of such unhealthy conditions. Various reports have been published over the last few years in order to reduce the risk of developing these diseases (Anon., 1983, 1984, 1994).

Variation in the diet helps to achieve a satisfactory balance of the intestinal flora with a nutritionally varied foods including dietary fibre, and fermented milks, such as yoghurt and bio-yoghurt, which promote useful probiotic bacteria or suppress harmful bacteria. For example, ingestion of dietary fibre including the non-digestible carbohydrates (*i.e.* water-soluble or water-insoluble) which have nutritional significance, causes an increase in the volume of faeces and dilution of noxious substances such as carcinogens produced by certain bacteria (Mitsuoka, 1996). The water-insoluble group of non-digestible carbohydrates, which may include wheat products, are believed to reduce the chances of colon cancer. However, the water-soluble fibres of the same cereal, for example bran and pectin, are believed to lower the serum cholesterol levels in the blood by binding the cholesterol present in the intestinal tract with bile acids, and as a consequence it is removed with the faeces (Vieira, 1996). Eastwood (1989) suggested that an adult should eat 30 g of coarse wheat bran in yoghurt a day along with the general diet of one's choice.

In spite of the fact that cereals alone are the most important source of energy and other important nutrients, they also contain some anti-nutritious components when consumed. Cereals lack in vitamins A (except yellow maize), B_{12} and C. Whole cereals contain phytic acid which may interfere with absorption of iron, Ca, and other trace elements, and they are also deficient in certain amino acids notably lysine (Kent and Evers, 1994). Dairy products are important sources of nutrients, such as protein, Ca, K, P and riboflavin (Miller *et al.*, 1995). These may include flavoured or unflavoured milk, yoghurt and other fermented milk products, cheese, butter, cream and various types of fortified, condensed and dried milk products. Furthermore, some milk components have unique functional properties, flavour and nutrition, and make them ideal ingredients for processed food and other dairy-based products (Rosenthal, 1991). In the United Kingdom (UK), all dairy products are consumed at a rate of 120 kg *per caput per* annum. Among these, the fresh dairy products such as cream, yoghurt, and Fromage Frais are the most dynamic growing milk product sectors except Mozzarella cheese. The sale of these products grew by 12% in value in 1992 (Wilson *et al.*, 1995).

Over the past decade, many consumers in North America and Europe have been modifying their eating habits for health reason (Tamime *et al.*, 1994). In United States (US), 8077 new products have been introduced (Rudolph, 1995), and in the UK over 3000 new products were launched (Selman, 1992). However, due to consumers demand for new products, fermented milks, yoghurt, yoghurt-related products and other products are highly nutritious and have a healthy image which are widely acceptable by consumers throughout Europe and North America.

Fermented milks including yoghurt have been consumed by humans for many centuries. Although they have a distinctive characteristics, flavour and are hygienically safer when compared with raw milk, their keeping quality at ambient temperature is limited. To prolong the shelf life of these products, different traditional methods have been practiced for centuries which may include fermentation, salting, heating (cooking and baking), drying, freezing, and/or addition of chemical agents (Rasic and Kurmann, 1978; Vieira, 1996). Consequently, a wide range of products have been developed, and some examples, are Strained yoghurt, Frozen yoghurt, Smoked yoghurt, Drinking yoghurt and Dried yoghurt. In the Middle Eastern countries, one of the traditional methods used to preserve the yoghurt is by mixing the fermented milk with cereals followed by sun drying. This product is known locally as 'Kishk'. The production methods for the manufacturing of the Kishk may differ from region to region, and even within the same country because of the traditional methods adopted. In general, low-fat yoghurt and Burghol (*e.g.* parboiled 'cracked' wheat) or wheat flour are widely used (van Veen *et al.*, 1969). In some cases, other additives such as tomato paste, red peppers, onions, turnips, garlic, herbs, dates or other vegetables have been used (Kurmann *et al.*, 1992). In the Sudan, de-hulled sorghum is used to prepare Um-kushuk which is closely related to the Kishk (Dirar, 1993), and in Egypt, Hassan and Hussein (1987) prepared laboratory-made Kishks using soya milk and chick-pea flour. The various generic names for Kishk-like products in different countries are Kurut (in Turkey), Kishk Siamy (in Egypt), Tamar Oggt (in Saudi Arabia), Chura (in India, Nepal and Tibet) and Katyk (in the Russian Republics).

According to Tamime and O'Connor (1995), Kishk as dish may be prepared in different ways as follows:-

- reconstitute small quantity with water followed by simmering gently over fire; when ready, this porridge-like product is normally consumed with bread, and herbs or onion may be added,
- add the powder during soup preparation,
- eat as biscuits on their own or with tea, and
- rehydrated in large quantity of water and consume as a beverage.

The nutritional properties of Kishk are very good because it contains both the milk and cereal nutrients. Such a combination of two food products is highly complementary in terms of nutrition, and each may mask the nutrient(s) deficiencies of the other. For example, milk is a good source of protein that makes up for the amino acids deficient in cereals, and similarly Burghol is a good source of iron which is deficient in milk (Tamime and O'Connor, 1995). Nevertheless, the nutritional value of Kishk is high, but very limited research work has been conducted in the past on:-

- the replacement of Burghol with other cereals such as rice, maize or chick-peas flour,
- the use of fresh milk (goat, sheep or cow) or reconstituted skimmed milk powder,
- the use of soya- or whey-based ingredients, and
- the use of different starter cultures for the preparation of the yoghurt.

In spite of research studies conducted in different laboratories in the world, there is still some considerable lack of information on Kishk. Therefore, it was decided that an attempt should be made to standardise the laboratory-made Kishk, modify the manufacturing stages and replace the Burghol with other cereals without ultimately affecting the quality of Kishk. Thus, the proposed research work will cover the following objectives:-

- To establish and standardise the manufacturing stages of laboratory-made Kishk.
- To establish the analytical techniques required to measure gross compositional quality, micro-nutrients and organoleptic properties.
- To compare the product quality and nutritional properties of Kishks made with different varieties of parboiled cracked oats and barley when compared with traditional Kishk made with wheat Burghol.
- To study the effect of Burghol technology on nutrient losses of 'cracked' oats, barley and wheat with the original grains.
- To assess the organoleptic qualities of these different types of Kishks when compared with Kishk made with wheat Burghol and Scottish porridge oats.
- To study the quality of Kishk made with (a) different wheat ingredients (*i.e.* Burghol and flour), (b) rolled oats and flour, and (c) by direct acidification and microbial fermentation.
- To investigate and identify the possible changes and/or interactions occurring during the secondary fermentation stage, including microscopy studies.

CHAPTER TWO:

LITERATURE REVIEW

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

2.1.1 Historical Background of Kishk and Related products

Fermented milks are well recognised as important food component in the human diet (Rasic and Kurmann, 1978; Tamime and Robinson, 1985, 1988b; Robinson and Tamime, 1990, 1993). The consumption of these foods might be dated back to the domestication of animals (cow, goat, sheep or buffalo) and cultivation of the land. At that time, Neolithic herds men kept the milk in animal skin bags or clay pots. In warm climates the temperature could reach 40°C, and under these conditions the milk fermented and produced an uncontrolled curd-type product like yoghurt (Helferich and Westhoff, 1980). The same authors reported another classical story in which a nomad wandered into the desert with fresh milk held in a goat's skin bag placed beside the body of his camel. Some hours later, he tried to drink the milk and was surprised to find a semi-solid mass or coagulum. This might be due to the heat from the camel's body producing the optimum conditions for the growth of indigenous micro-organisms present in milk, mainly lactic acid bacteria.

According to another legend, an angel brought down the pot which contained the first yoghurt or Leben, while another claims that the ancient Turks, who were Buddhists, used to offer yoghurt to the angels and stars who protected them. In the Bible it is recorded that when the Patriarch Abraham entertained three angels, he put before them soured and sweet milk from cows and goats (Rasic and Kurmann, 1978). In Asia, the first sour milk originated in the 8th century, and the Turks called the product "Yogurut" which was subsequently changed to "Yoghurt" in 11th century.

In the West, yoghurt was introduced in the 16th century when a Turkish doctor from the Constantinople was invited to cure King Francois I of France of a digestive disorder. The doctor brought his own herd of sheep and goats to prepare fresh yoghurt for the king, but after curing the king's ailment, he left with his herd without revealing his secret of turning milk into yoghurt. Eventually the West acquired the art of yoghurt making (Bahl, 1996). Different traditional fermented milk products have been produced for centuries in many countries such as the Balkans, eastern Mediterranean, in western Asia and Turkistan (Figure 2.1). Most of these products are home-made from whole milk (cow, sheep, goat or combination of these) or from buttermilk. Nomads, desert dwellers and people in rural areas tend to turn surplus summer milk into different products with extended shelf-lives (Tamime and O'Connor, 1995).

Unlike fermented milks, cereals, *i.e.* wheat, were used as human food in prehistoric time. There is archaeological evidence that it was grown about 5000 B.C. in Iraq (Kent and Evers, 1994). It has been cultivated around the Eastern Mediterranean and Mesopotamia for at least 5000-6000 years. The durum wheat was found in Egypt in some tombs about 4000 B.C. (Matz, 1991). According to the same author, cultivation of wheat began around 6000 years ago in Syria-Palestine area and spread West and South into Egypt and East into Iran. From Iran, wheat spread to India, China, Russia, and Turkistan. The first wheat to reach Europe was in the form of einkorn and emmer about 3000 B.C. The grain was first grown in New England and Virginia by English colonialists early in the 17th century.

The exact date and origin of dried fermented milk products is unknown. There is no precise record available when it was first made and used for food. It is possible to suggest that dried fermented milk products may have evolved, in part, for the preservation of highly perishable dairy product thousands of years ago. The addition of cereal, for example wheat flour, could have been used for bulking purposes to reduce the moisture content and hence to enhance the drying stage, or was used as a staple food ingredient. There is evidence that such dried product was used by the Roman Emperor Elagabalum (A.D. 218-222) who mentioned two recipes of soured milk preparations. The first was called "Opus lactarum" which was composed of soured milk, honey, flour and fruits, and the other was called "Oxygala" made by mixing sour milk, vegetables and spices, such as marjoram, mentha,

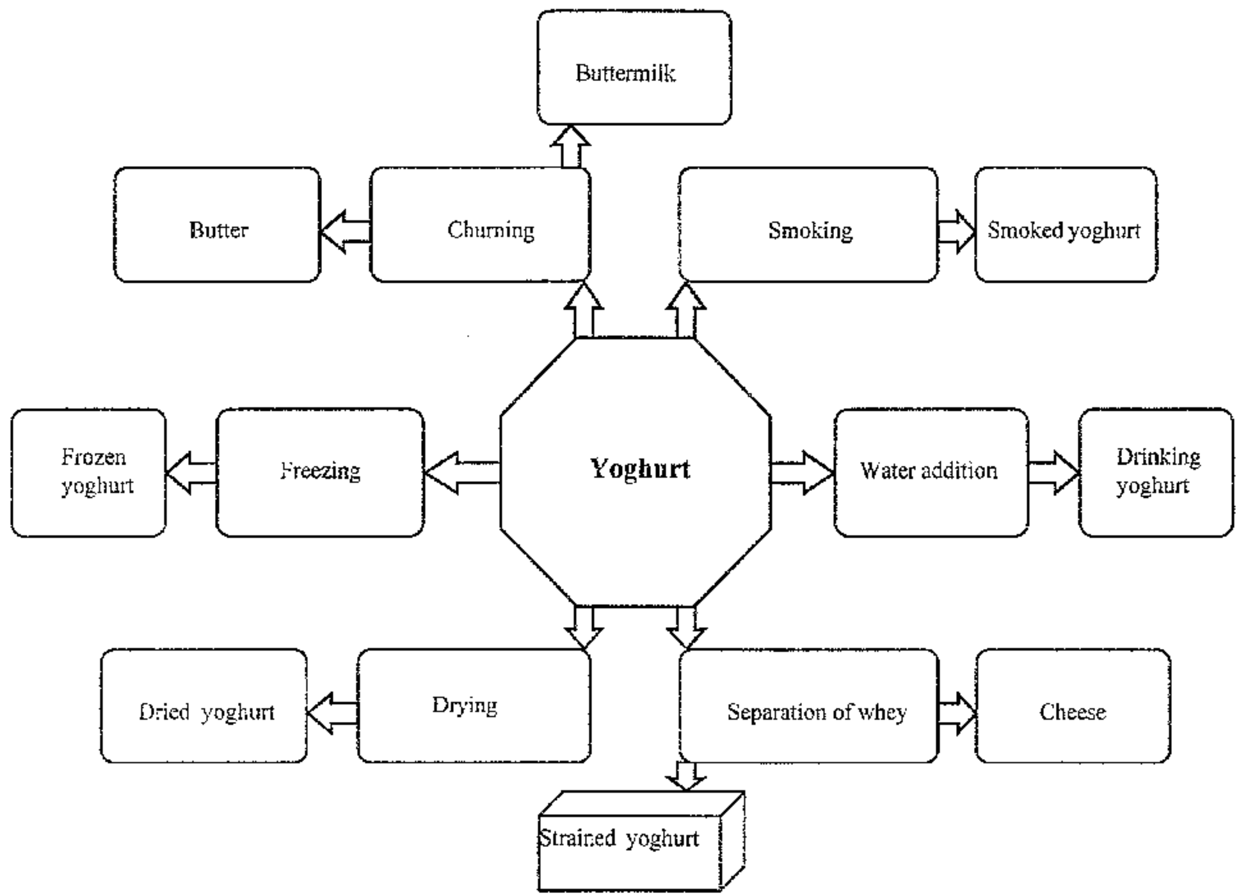

Figure 2.1 An illustration using different processing methods for the production of yoghurt related products (A. Y. Tamime personal communication).

coriander, onion, thyme and chive-garlic (Rasic and Kurmann, 1978).

It is also possible to suggest that the ancient Egyptians were interested in keeping cows for milk production and processing. They were familiar with many of the methods and utensils used for the processing of different foods. Many illustrations of the milking of cows and milk processing are shown in drawings and carvings on the walls of their old temples and ruins. The Egyptian museums exhibit many of the utensils, earthenware jars, wooden pots, animal pelts and many pieces of stone equipment used by the ancient Egyptians. Some of these are still being used in rural areas in Egypt to produce different dairy products using very old and traditional methods (El-Gendy, 1983).

According to some sources, a dried type of yoghurt called Kurut originated in Asia around the 8th century where the ancient Turks lived as nomads (Rasic and Kurmann, 1978), and another dried product called Kishk was reported by Tamime and O'Connor (1995). The Kishk and related products were originally obtained by mixing the fermented milk *i.e.* low-fat yoghurt or buttermilk of churned full-fat yoghurt with cereals (parboiled cracked wheat known as Burghol) (Tamime and O'Connor, 1995).

2.1.2 Definition and Classification

The exact definition of Kishk is not well established. It is extremely difficult to give an appropriate definition to such product because it has been traditionally produced on systems which may differ from region to region. Thus, many names have been given to such dried fermented milk products (see Figure 2.2). According to Tamime and O'Connor (1995), such names could be attributed to:

- the region or area of manufacture,
- the type of milk used,
- borrowed or made up names,
- spelling according to the region or country, and
- the type of additives used.

However, the same authors have suggested that the word "Kishk" should be reserved for

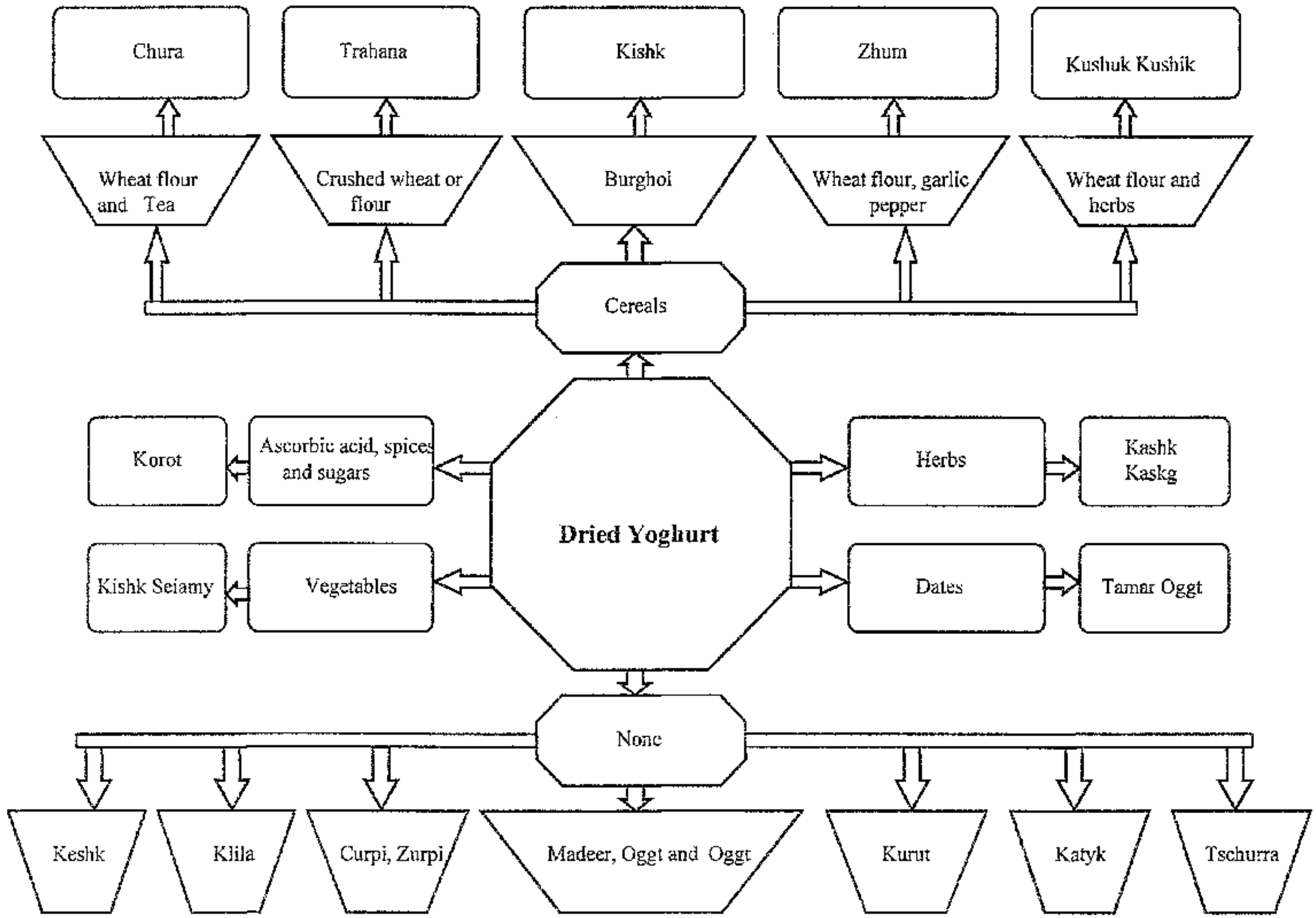

Figure 2.2 Classification of Kishk and related products. Adapted from Tamime and O' Connor (1995).

the product containing cereal, mainly parboiled cracked wheat (*i.e.* Burghol) or wheat flour. Alternatively, the Kishk products could be classified as: (a) natural (with no additives except Burghol) and (b) flavoured (with vegetables, spices, herbs or fruits). It is evident that the product may contain fermented milk, cereals and/or other additives, and therefore, taking into account these ingredients it is possible to propose a detailed classification of Kishk and related products which is shown in Figure 2.2.

2.1.3 Pattern of production

The traditional dried fermented milk products (Figure 2.2) are produced and consumed in many countries of the world and are very popular locally. No data is available on the annual production and consumption figures of these products; however, according to Platt (1964) and Kurmann *et al.* (1992) the estimated *per caput* annual consumption of Kishk in the northern region of Iraq ranged between 20 and 30 kg in 1960, and in Turkey the consumption was at a level of 8 kg. According to the FAO (1990) the average yearly production of Kishk in Lebanon was about 1000 tonnes. It is evident that if these production figures in the Lebanon, Turkey and Iraq reflect the possible trend in consumption and/or production of Kishk in all the different countries of the world, then it is possible to estimate that world production figures of dried fermented milk containing cereals could be high.

2.2 Technology of Kishk manufacture

2.2.1 Introduction

The technology of Kishk-making is based on the traditional methods and may differ from one place to an other place. However, the main components of the mixture are fermented milk, for example low fat yoghurt and/or buttermilk of churned full-fat yoghurt, and cereals [(parboiled cracked wheat, *i.e.* Burghol or Bulgur) (Tamime and O'Connor, 1995)], and some times miscellaneous additives [(*e.g.* tomato paste, red peppers and chopped onions, turnips (van Veen *et al.*, 1969; Alnouri *et al.*, 1974) or spices (Farr, 1982)] may be added in order to flavour the product.

2.2.2 Fermented milk

Fermented milks (low fat yoghurt, buttermilk of churned full-fat yoghurt, strained yoghurt (labneh), skimmed milk yoghurt and/or whole milk yoghurt) are used during the manufacture of Kishk and related products (Tamime and O'Conner, 1995). The use of such types of fermented milks may influence the quality of the products due to the different chemical composition (see Table 2.1). The manufacturing stages of indigenous fermented foods, including dried fermented milk have been reviewed by van Veen and Steinkraus (1970), Steinkraus (1983), El-Gendy (1983, 1986), Jandal (1989) and Kurmann *et al.* (1992).

2.2.2.1 Milk as raw materials for fermented milks

Fermented milks for Kishk-making are prepared from the milk of different species of mammals (sheep, goat, cow, buffalo, camel). Goat and buffalo milks are widely used to prepare Kishk in Lebanon and Egypt, respectively, while camel's milk products are used in North Africa (Tamime and O'Connor, 1995). Milk as a raw material may affect the quality of the yoghurt or any type of fermented milks. The chemical composition of milk from different mammals varies considerably, and within breeds of the same species (Table 2.2). Such differences can influence the physical properties of the yoghurt (Rasic and Kurmann, 1978) which may affect the quality of Kishk. Other factors that can influence the chemical composition of these milks are: stage of lactation, climate, diet and season of the year (Juarez and Ramos, 1984).

2.2.2.2 Standardisation and fortification

The use of concentrated buttermilk and/or skimmed milk yoghurt has been reported to prepare Kishk and/or related products (El-Sadek *et al.*, 1958; van Veen *et al.*, 1969; Jandal, 1989). This may be to preserve their surplus milk (Tamime and O'Connor, 1995) and/or prepare inexpensive dried products (Salama, 1988). However, it is evident that the use of such types of fermented milk as a base medium for Kishk and/or related products may give products with a low fat content.

Table 2.1 Chemical composition (g 100 g^{-1}) of fermented milks.

Product	Moisture	Protein	Fat	Carbohydrate
Strained yoghurt (Labneh)	74.0-78.0	8.8-9.0	9.0-10.3	3.8-4.0
Whole milk yoghurt (plain)	81.9	5.7	3.0	7.8
Low fat yoghurt	84.9	5.1	0.8	7.5
Whey (sweet)	93.3	1.0	0.2	5.1
Soya yoghurt	82.4	5.0	4.2	3.9
Buttermilk	90.4	3.4	0.5	5.0

Data adapted from Holland *et al.* (1989, 1991) and Tamime and Robinson (1985).

Table 2.2 Chemical composition (g 100g-¹) of various species of mammals.

Species/breeds	Fat	Protein	Lactose	Ash
Different species				
Buffalo	8.0	4.2	4.9	0.8
Camel	4.2	3.7	4.1	0.9
Cow	3.9	3.2	4.6	0.7
Goat	3.6	3.3	4.6	0.8
Sheep	7.1	5.7	4.6	0.9
Different cow's breeds				
Ayrshire	4.0	3.3	4.6	0.7
Brown Swiss	3.8	3.2	4.8	0.7
Guernsey	4.6	3.5	4.8	0.7
Holstein	3.6	3.0	4.6	0.7
Jersey	5.0	3.7	4.7	0.8

Data compiled from Tamime and Robinson (1985) and Harding (1995).

There is no legal standard for the traditional fermented milk used for the manufacture of the Kishk and related products. However, the fat level can be standardised according to current consumer demand where in developed countries, policy makers and health educators warn the public to reduce the fat intake in their food (Marshall, 1995). In most countries of the world the fat content of yoghurt ranges between 0.1 and 10 g 100 g^{-1} (Tamime and Robinson, 1985). However, it is safe to assume that the fat content of yoghurt can be adjusted to the desired level by one of the following methods reported by Tamime (1996):-

- The addition of skimmed milk to whole milk
- Addition of cream and / or anhydrous milkfat (AMF) to skimmed milk
- Separation of fat from milk, and/or
- Addition of whole milk to skimmed milk

The milk solids-not-fat (MSNF) (normally lactose, protein and mineral) also play important role for the manufacture of yoghurt. These improve the texture and consistency of the product when milk is fortified from 8.5 to 12-14 g 100 g^{-1} (Tamime and Robinson, 1985). The methods used for the fortification of MSNF of the yoghurt base have been reported by Tamime (1996) as:-

- Addition of powders
- Concentration
  - Evaporation (EV)
  - Reverse osmosis (RO)
  - Ultra-filtration (UF)

However, there is no evidence in published scientific articles of the fortification of MSNF of the yoghurt base used for the production of Kishk and related products.

2.2.2.3 Homogenisation

The process of homogenisation is not reported during the preparation of the yoghurt base for the manufacture of Kishk and/or related products. This may be due to the use of the surplus milk by Nomads, desert dwellers and people of rural areas, or the utilisation of the by-product of churned-buttermilk (El-Sadek *et al.*, 1958; Morcos *et al.*, 1973). In some instances, homogenised milk purchased from the local markets has been used for Kishk-making (van Veen *et al.*, 1969; Hafez and Hamada, 1984).

Homogenisation of the yoghurt base has some beneficial effects, because the milk fat globules break up mechanically, and the smaller size globule that do not rise to the surface to form a cream line. During the homogenisation stage, the milk is forced through a tiny valve under great pressure, for example, 15-20 MPa at *ca.* 65°C (Varnam and Sutherland, 1994). This causes shattering of the fat globules, so reducing the size to about 1μm. These small fat globules are naturally stabilised by absorption with casein micelles and remain uniformly distributed in the milk (Harding, 1995). Also any residual undisolved particles of milk powders or stabilisers will be dispersed adequately in the milk as result of the homogenisation effect (Robinson and Tamime, 1993). As a consequence, yoghurt made with homogenised milk have different rheological properties from yoghurt made from unhomogenised milk (Swaisgood, 1996). Homogenisation is usually carried out prior to the heat treatment of the milk but, in some cases, it may take place after the heat treatment as this gives a better consistency to the final product; but there is a risk of re-contamination (Puhan, 1988).

2.2.2.4 Heat treatment

Heating is considered as an essential practice for the preparation of the yoghurt base. The most significant effects of heat-induced changes in milk constituents (Rasic and Kurmann, 1978; Tamime and Deeth, 1980; Robinson and Tamime, 1981, 1986; Puhan, 1988; Varnam and Sutherland, 1994) could be summarised as follows :-

- Heat treatment stimulates the growth of the starter culture bacteria by reducing the oxygen content of milk.
- Redistribution of minerals, *i.e.* calcium , magnesium, and phosphorous ions, between the soluble and colloidal form which tends to reduce coagulation time.
- Destruction of pathogenic bacteria.
- Denaturation of the whey proteins and induction of interactions between β-lactoglobulin and α-lactalbumin with κ-casein; and such interactions are considered to be the important physico-chemical changes which improve the consistency of the

coagulum.

In contrast, there are very few drawbacks due to the heating which were reported by Tamime and Deeth (1980). For example, the amount of lysine is reduced to a limited degree (*i.e.* 0.3 g 100 g^{-1}) due to the interaction between the amino group ($-NH_2$) of the lysine with lactose. Some vitamins are also destroyed and most affected are ascorbic acid, B_1, B_{12} and folic acid. However, folic acid and niacin can be synthesised by the yoghurt starter culture.

Traditionally, the yoghurt base for Kishk-making was boiled vigorously for 1 or 10 min (van Veen *et al.*, 1969; Hafez and Hamada, 1984) or heated on 65°C for 5 min (Hamad and Fields, 1982). Varnam and Sutherland (1994) recommended the heat treatment of milk at 80-85°C for 30 min (batch process) or at 90-95°C for 10 min in a plate heat exchanger.

2.2.2.5 Fermentation

Fermentation is a process whereby beneficial bacteria are encouraged to grow in order to increase the acidity or alcohol content of a food. This may prevent the growth of undesirable micro-organisms, for example, spoilage and food poisoning bacteria (Fellows, 1997). The process of fermentation has been used by mankind for thousands of years as a useful method to prevent the spoilage of milk and to extend its shelf life (Foster *et al.*, 1957). It is evident that the micro-organisms used in fermented milks change the composition of the milk base (Harding, 1995), and several types of fermentation may occur in milk. The nature of their end-products is different and may adversely affect the product quality. Lactic acid fermentation is the most important and popular type used in the dairy industry (Kosikowski and Mistry, 1997). For example, lactic acid resulting from the biochemical activity of lactic acid bacteria is considered the main compound which shows bacteriostatic, and in some cases bactericidal, effects against putrefactive micro-organisms such as spore-forming and coliform bacteria (Oberman, 1985). Some examples of such fermentations were reported by Robinson and Tamime (1990) and Varnam and Sutherland (1994), and have been classified into the following categories:-

- Lactic acid fermentation

a) Mesophilic lactic acid fermentation (*e.g.* cultured buttermilk, buttermilk, cultured cream, Filmjolk, Scandinavian ropy milks, Taetmjolk, Maziwalala and/or Ymer).

b) Thermophilic lactic acid fermentation (*e.g.* yoghurt, Laban, Zabadi, Acid buttermilk, strained yoghurt or Labneh, Chakka, Shirkand, Skyr and/or Bulgarian buttermilk).

c) Therapeutic lactic acid fermentation (*e.g.* Acidophilus milk, Yakult, Acidophilus-Bifidus (AB) yoghurts, Bioghurt®, Biograde® and/or Bifighurt®).

- Lactic acid/yeast fermentation (*e.g.* Kefir, Koumiss and/or Acidophylus-yeast milk).
- Lactic acid/mould fermentation (*e.g.* Villi).

2.2.2.6 Starter cultures

Since fermentation of milk was developed independently in different parts of the world, the organisms responsible differ, and such differences are reflected in the types of cultured milk that are produced (Nursten, 1997). However, an "artisan" or "natural" starter culture (a small quantity of previous prepared yoghurt) and/or a pure or selected starter cultures have been used to achieve the fermentation of the base medium (Rasic and Kurmann, 1978).

Traditionally, Kishk has been made from milk fermented with undefined starter cultures (Tamime and O'Connor, 1995); however, defined starter cultures have been used in Kishk-making. For example, *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* have been used to ferment the milk (van Veen *et al.*, 1969; Robinson, 1978; Hafez and Hamada, 1984; Abou-Donia *et al.*, 1991). According to Abou-Donia *et al.* (1991) when *Lactobacillus acidophilus* or *Lactobacillus paracasei* subsp. *paracasei* was added to the yoghurt starter culture, no significant different was found in the quality of Kishk. While, in Oggt-making, the milk was fermented with lactococci and *Leuconostoc* spp. (Al-Mohizea *et al.*, 1988). The fermentation with pure single strains of *Lactococcus lactis* subsp. *lactis*, *Lactobacillus plantarum*, *Saccharomyces rouxii*, yoghurt starter culture or combinations of these was studied by Alnouri *et al.* (1974) for the production of Kishk, and they recommended the use of mixed cultures consisting of lactococci, lactobacilli and yeast. The changes that occur in milk due to the activity of the starter cultures were reported by Robinson and Tamime (1990) as follows:-

- Lactose is hydrolysed inside the bacterial cell and utilised for the production of lactic acid and other organic compounds.
- Destabilisation of the calcium-caseinate-phosphate complex by the lactic acid which results in the formation of acid-gel.
- Production of flavour compounds such as acetaldehyde, acetone, acetoin and/or diacetyl.
- The proteolytic enzymes from the starter cultures may produce flavour compounds which are important in some dairy products.
- Some degree of fat degradation may take place which significantly contributes towards the flavour of the product.

2.2.2.7 Buttermilk and Labneh

Fermented milk used for Kishk-making in Southern province of Egypt was buttermilk. Traditionally, the method of processing was to place the evening milk in leather bags and leave until the next day when the morning milk was also poured into the same bags. Later, the salt was added and the leather bag was shaken for some time in order to coalesce the fat globules to form butter granules which were removed, and the buttermilk was then transferred to another leather bag larger in size to that used for churning. The buttermilk was transferred at weekly intervals to special eathernware containers and covered. Several lots were collected, and an extra amount of salt was added to preserve the product. These containers were left for some time for evaporation to concentrate the buttermilk which was later used to make the Kishk (El-Sadek *et al.*, 1958; Morcos *et al.*, 1973; El-Gendy, 1983).

Tamime and Robinson (1985) reported that concentrated fermented milk products are known by different names such as Tan and Than in Armenia, Torba, Kurut, and/or Tulum in Turkey, Leben Zeer in Egypt, Labneh or Lebneh in majority of Arab countries, and Paneer similar to Labneh in Pakistan and India (Campbell-Platt, 1987). Traditionally, the Labneh is made by straining natural yoghurt using a cloth bags, animal skin, or earthenware container (Tamime and Robinson, 1988a; Robinson and Tamime, 1993). However, El-Samragy *et al.* (1988) have produced Labneh (21-22% total solids) from fresh buttermilk obtained from a commercial butter factory, and at present Labneh can be produced commercially by using nozzle separators or ultra-filtration (Robinson and Tamime, 1993). In the former method, fermented skimmed milk is used, while in the UF process full- or low-fat fermented milk could be used; for Kishk-making, low-fat Labneh could be employed. Nevertheless, in the Middle East, Labneh may be used as a raw material for the manufacture of some traditional products, for example, Labneh Anabaris (shaped in balls and covered with oil), Chanklich (yoghurt mixed with spices and herbs) and/or Kishk (yoghurt mixed with parboiled cracked wheat or wheat flour) (Tamime and Robinson, 1985).

2.2.3 Cereals

2.2.3.1 Introduction

Cereals (*i.e.* wheat, rice, maize (corn), barley, oats, and rye) are the most important source of carbohydrate available for man and form the staple food in most countries of the world. They may be used either as whole grain (*e.g.* rice) or ground into flour (*e.g.* wheat flour) (Gaman and Sherrington, 1990). Cereals are rarely consumed alone because of their anti-nutritious components, but are consumed together with other foods which may mutually compensate for each other's deficiencies (Kent and Evers, 1994). According to Ranhotra (1994) wheat-based foods are considered the major source of energy, protein and various vitamins and minerals. Thus, parboiled wheat and /or wheat flour is widely used for Kishk-making (El-Sadek *et al.*, 1958; Alnouri *et al.*, 1974; Cadena and Robinson, 1979; Hamad and Fields, 1982; El-Gendy, 1983; Atia and Khattab, 1985; Jandal, 1989; Kurmann *et al.*, 1992). However, some studies on Kishk have been conducted by replacing the parboiled cracked wheat with other additives which are nutritionally richer, such as gram flour, tomato juice (van Veen *et al.*, 1969), chick peas, soybean (Hassan and Hussein, 1987; Oner *et al.*, 1993), and rice flour, crushed maize/whole maize flour (Abou-Donia *et al.*, 1991). For comparative purposes, the chemical composition of some cereals is illustrated in Table 2.3.

Table 2.3 Chemical composition (g 100 g^{-1}) of various cereals and flours.

Material	Moisture	Protein	Fat	Ash	Carbohydrate	Starch	Fibre
Wheat (meal)	14.0	12.7	2.2	—	63.9	—	—
Burghol (wheat)	9.3	9.7	1.7	—	76.3	—	—
Wheat flour (plain)	14.0	9.4	1.3	—	77.7	76.2	3.1[E]
Oat (groat)	7.5	17.0	7.7	2.0	—	—	1.6
Porridge oat (rolled oat)	—[NR]	13.3	7.6	2.0	74.7	—	0.9
Oat flour	—	14.2	7.9	2.0	43.4	—	1.1
Barley (pearl raw)	10.6	7.9	1.7	—	83.6	27.6	5.9[S]
Soybean flour							
Full fat	7.0	36.8	23.5	—	23.5	12.3	11.2[E]
Low fat	7.0	45.3	7.2	—	28.2	14.8	13.3[S]
Rice flour	11.8	6.4	0.8	—	80.1	80.1	2.0[E]
Maize flour	—	8.1	1.5	0.7	88.7	—	1.0

Data compiled from Holland *et al.* (1988), Matz (1991) and Kent and Evers (1994).

[NR] Not reported. [E] Data calculated by Englyst method. [S] Data calculated by Southgate method.

2.2.3.2 Production of parboiled cracked wheat (Burghol)

Parboiled cracked wheat is known by different names in different countries such as Bourghoul, Burghul, Bulgur (Tamime and O'Connor, 1995), Peeled Bulgur or Ricena (Kent and Evers, 1994). The basic process for Burghol production consists of boiling whole wheat until the starch has been substantially all gelatinised, drying the whole grains until they become hard, then rubbing off the bran. This processing technique for the manufacture of Burghol has been used for centuries in Turkey (home and industrial scales) and some of neighbouring countries. It is probably made from durum wheat and/or red wheat known as Wurld wheat. "Bulgur-izing" has been suggested from time to time as a technique which should be widened in its distribution (Matz, 1991) because the process to gelatinise the starch (Neufeld *et al.*, 1957) alters its solubility through the formation of amylose and amylopectin complexes (Priestly, 1976a, 1976b; 1977). This process improves the nutritional properties of Burghol. However, the fat, ash and crude fibre levels are slightly lower than the wheat kernel from which it has been made, but the protein level is unchanged (Kent and Evers, 1994). Some methods for the preparation of cereals for Kishk-making are shown in Table 2.4.

In general, the traditional method for the production of Burghol during Kishk manufacturing starts with cleaning and washing the wheat grain to remove any foreign materials, the kernels are blanched in boiling water until soft and spread on a mat in the sun to dry. Then the grains are moistened with water and 'cracked' into different fractions, for example, fine or coarse, and stored until required (Tamime and O'Connor, 1995).

2.2.3.3 Wheat flour

Unlike Burghol, wheat flour can be also used during Kishk-making, and it could be associated with improved water absorption properties when compared to Burghol. The outer layer of the wheat is somewhat brittle because of the high fibre content, and to transform the grain into a more digestible form; it is milled into flour (Gaman and Sherrington, 1991). The milling may breaks the outer layer into moderately small, thin and jagged pieces of bran and, by rupturing some of the starch granules, increases the water

Table 2.4 Methods used for preparation of cereals or Burghol making.

Processing stages	References
Boil fresh wheat grain in water for a long time until become soft, spread over mats and dry in the sun followed by crushing in a hand mill.	El-Sadek *et al.* (1958) and Kurmann *et al.* (1992)
Clean red or white soft wheat, cook in multi-stage process by gradually increasing the moisture content by spraying with water, heat the wheat at 95°C with steam at 0.21 MPa pressure for 1.5 min, and dry with air at 66°C to about 10 g moisture 100 g^{-1} and finally crack.	Schäfer (1962)
Treat the wheat grain with sodium hydroxide, remove the loosened bran by vigorous washing with warm water, treat the grain with dilute acetic acid in order to improve the colour and dry.	Shephered *et al.* (1965)
Place wheat grain in large cooking pans, cover with water and heat slowly to boiling and simmer until soft; wash the cooked wheat with cold water, spread on mats to dry, grind in stone mills, sieve and remove the husk.	Morcos *et al.* (1973)
Wash the wheat kernels and remove any foreign materials; boil the grains for an hour in an open kettle, spread on ground to dry, remove the chaff and mill the grains into course flours.	Robinson and Cadena (1978)
Boil fresh wheat grains (belila) in water until they are soft, spread over mats, dry in the sun and crush using stone hard mill named Rahaia.	El-Gendy (1983)
Boil wheat grain in water and dry in a sunny place for around a week; crush the dried product, sieve and dispose of the smooth particles.	Atia and Khattab (1985)

Table 2.4 (continued)

Processing stages	References
Soak the wheat in a succession of three tanks (~ 8 h) in order to increase the moisture content of the grains cook the grain with stream at a pressure of 0.15 - 0.3 MPa for 70-90 s and dry to 10-11 g moisture 100 g^{-1}, remove the outer layers, mill the grain and size the Burghol.	Certel *et al.* (1989)
Wash and condition the wheat by boiling for few hours, drain off the excess liquid and air dry the kernels; pound or rub the dried cooked kernels with a wooden pestle to break off the bran and remove it by sifting or winnowing.	Matz (1991)
Soak or pre-cook wheat in water at 60°C temperature for 4 h, drain off excess water, place in a mesh basket suspended in a steam autoclave, cook at 0.48 MPa for 3 min, dry on wire-mesh trays in a cabinet drier with an air velocity of 3.28 m s^{-1} for 24 h, , polish the kernel in Mcgill rice mill, grind the polished kernels in buhr mill and separate the Burghol by sieving (10 and 20 mesh) for coarse and fine particles, respectively.	
Remove stalks, dirt and other cereal grains from soft wheat (varieties Stork, Jury, Italian and Slalibi) by using a rotatory cylindrical machine locally known as "ghorbal". The same machine sizes the wheat into three fractions: (a) large (b) small and (c) broken. Steep large grains in boiling water for 1 h until soft and then dry in the sun for 24 h. On the following day, moist the dried grains with water (~20 g 100 g^{-1}), crack and dehusk. Separate the Burghol from the husk by winnowing , and later sized as coarse or fine. The coarse fraction is used for Kishk-making.	Tamime and O`Conner (1995)

absorption capacity of the wheat (Pomeranz, 1991). It may be used in the form of whole meal flour, which contains the germ, bran, and scutellum as well as the powdered endosperm (Fox and Cameron, 1995) or as refined flour obtained by the milling of wheat in several fractions. For example, extra short or fancy-patent flour, short or first-patent flour, short-patent flour (high in starch and low in protein content), medium-patent flour (higher content of protein and relatively less starch), long-patent flour (rather high protein content) and straight-flour (McWilliams, 1989). The use of such flours may influence the quality of the manufacture product(s).

2.2.3.4 Miscellaneous additives

The addition of additives, such as vegetables, garlic, herbs, spices, tea, ascorbic acid, sugars and/or dates (Tamime and O'Connor, 1995), turnips (Alnouri *et al.*, 1974), tomato paste, red pepper, and chapped onion, mints, paprika, green pepper, black pepper (van Veen *et al.*, 1969; Oner *et al.*, 1993; Ibanoglu *et al.*, 1995) have been reported either beside the main cereals (*i.e.* Burghol) or alone with fermented milk for the production of Kishk and related products. These additives are used to enhance the flavour of the product and make it more attractive and appetising.

2.2.4 Kishk-making

2.2.4.1 Introduction

The methods for the preparation of Kishk may differ from one place to another because these processes are based on traditional systems. In general, the traditional method for the manufacture of Kishk starts with the preparation of cereals normally wheat (see Table 2.4) and low-fat fermented milks. Two or more parts of yoghurt are mixed with one part of Burghol or wheat flour and the 'dough-like' mixture is allowed to ferment for five days or more. Afterwards, the dough mixture is formed into small nuggets and dried in the sun. Thus, the traditional Lebanese Kishk is made by mixing Burghol (1 part), yoghurt (4 parts) and salt 6%. The yoghurt is added to the Burghol in small portions up to 6 days, and the mixture is kneaded daily. The temperature is maintained at ~ 35°C. The dried Kishk nuggets are then milled to powder at granaries and either packed in cloth or plastic bags or large bins (Tamime and O'Connor, 1995).

2.2.4.2 Mixing methods of Kishk components

The mixing of the Kishk components (fermented milk, cereals and other additives) depends upon the method used for its production. Garnier (1957) placed the Burghol in an earthenware pot (maajen) to which a small amount of boiling water was added in order to burst the grain, and the mixture was left to dry for 5-6 h. The cereal paste obtained was laid on a tray and mixed with small quantities of Leben, Labneh and salt to obtain a homogeneous mixture, and later transferred to the 'maajen'. Further Leben, Labneh and salt were added and mixed after every second day until 15 days, followed by drying and milling. While in Egypt, the parboiled crushed wheat was slightly moistened with salted boiling water, mixed with concentrated buttermilk that had been diluted with water and raw milk to assume a thin creamy consistency (El-Sadek *et al.*, 1958). However, Morcos *et al.* (1973) placed coarse, crushed parboiled wheat in a large pot, moistened it with slightly salted boiling water mixed with raw milk or Laban Zeer diluted with water. The mixture was stirred to obtain homogeneous paste called 'hama' and left for 24 h. After that, it was kneaded by hand and Laban Zeer diluted with water or raw milk was added to give a syrupy consistency (*i.e.* twice the volume added before) and left for fermentation. Different proportions of cereals, fermented milks and other additives have been used during Kishk-making, and some examples are shown in Table 2.5.

2.2.4.3 Secondary Fermentation

As reported elsewhere, the fermentation of milk by lactic acid starter cultures is well established and has been widely researched in many laboratories. However, the process of secondary fermentation during Kishk-making starts after mixing the yoghurt with cereals, and the mixture is allowed to ferment for five days or more. The possible changes and/or interactions occurring during this period are not well established, and have not, so far as I am aware, been properly investigated.

Table 2.5 **Ingredients used in the mixture of Kishk and/or related products and their mixing ratio.**

Fermented milks	Cereals	Ratio	Additives	References
Yoghurt + Labneh	Whole-wheat meal	2+2.0 : 1	—	Platt (1964)
Fermented buttermilk	Wheat flour or Burghol	2.0 : 1 or more	Tomato paste, red pepper, chopped onion and salt	van Veen *et al.* (1969)
Yoghurt	Whole wheat flour	3.0 : 1	—	Robinson and Cadena (1978)
Concentrated buttermilk	Burghol	—NR	Salt	Basson and Abuirmeileh (1980)
Yoghurt	Burghol	2.0 : 1	—	Hamad and Field (1982)
Cultured whey	Burghol	2.0 : 1	—	
Goat's milk yoghurt	Burghol	4.0 : 1	Salt	FAO (1982)
Concentrated buttermilk	Burghol	—	Spices	Farr (1982)
Yoghurt	Burghol	2.0 : 1	—	Hafez and Hamada (1984)
Soybean yoghurt	Burghol	2.0 : 1	—	
Yoghurt+soybean yoghurt	Burghol	1+1.0 : 1	—	
Pasteurised milk (cow sheep or goat)+yoghurt	Burghol	2+0.5 : 1	—	FAO (1990)
Fermented milk	Burghol or wheat flour	2.0 : 1	Salt (3%)	Dagher (1991)

Table 2.5 (continued)

Fermented milks	Cereals	Ratio	Additives	References
Cultured skimmed milk or whole milk curd (Laban rayeb)	crushed parboiled wheat	2.0 : 1	Salt	Damir (1992)
Soured skimmed milk	Burghol	2.0 : 1	—	Salama *et al.* (1992)
Yoghurt	Wheat flour	1.0 : 1	—	Lazos *et al.* (1993)
Whey	Wheat flour	1.5 : 1		
Yoghurt	Soybean flour	—	Tomato, onion, salt, green	Oner *et al.* (1993)
	Soybean flour+ wheat flour	—	pepper, red pepper, black	
	Soybean flour+ wheat flour	—	pepper and mint	
Yoghurt	White flour	1.0 : 2	Tomato puree, chopped	Ibanoglu *et al.* (1995)
	Whole meal flour	1.0 : 2	onion, salt, paprika, dill,	
	White flour	2.0 : 2	Tarhana otu	

NR Not reported.

2.2.4.4 Drying

The main purpose of drying is to preserve the food by removing the water that is needed for microbial growth and enzymic activity (Fellows, 1997). Sun drying is one of the oldest methods, and has been used for centuries during the manufacturing of Kishk. Traditionally, this method of drying is used in places where there is an abundance of sun during the year. Thus, the fermented milk/cereal mixture is shaped into small balls, nuggets or small cakes, spreading over straw mats or trays and left up to 7 days in the sun to dry (Garnier, 1957; Platt, 1964; Morcos *et al.*, 1973; Basson and Abuirmeileh, 1980; FAO, 1982; El-Gendy, 1983; Al-Ruqaie *et al.*, 1987; Dagher, 1991). This long drying time may cause nutritional damage of the product. The nutrients sensitive to pH, oxygen, light and heat or a combination of these, may be damaged. For example, fat-soluble vitamins may be lost by interaction with the peroxides produced by fat oxidation; the losses of water-soluble vitamins, which are more stable to heat and oxidation, rarely exceed 5-10% (Fellows, 1988). However, Taoukis and Labuza (1996) reported losses in certain vitamins, those are susceptible to heat (*e.g.* C, thiamine, folate, B_6) and to oxidation (*e.g.* C, D, E, A). Lysine may react with sugars and form unavailable lysine-sugar complexes *i.e.* lactulose-lysine (Erbersdobler and Dehn-Müller, 1989).

In recent times, the development of modern and novel drying techniques has helped to develop higher quality food products, and some of these techniques have been used in various laboratories to dry fermented milk/cereal mixtures. For example, oven drying at 32°C for 5 days (Salama *et al.*, 1992), air drying at temperatures ranging from 43° to 55°C up to 46 h (Hamad and Fields, 1982; Hafez and Hamada, 1984; Hassan and Hussein, 1987; Abou-Donia *et al.*, 1991), freeze- and roller-drying (van Veen *et al.*, 1969; Robinson and Cadena, 1978), fan-drying at room temperature or at 45°C over night (Al-Ruqaie *et al.*, 1987) or a vacuum oven at 45°C for 8-10 h (Al-Mohizea *et al.*, 1988) have been used successfully during Kishk-making.

2.3 Compositional quality of Kishk

2.3.1 Gross chemical composition

The commercial and laboratory-made Kishks were reviewed by Tamime and O'Connor (1995), and they suggest a wide variation in the gross chemical composition of the product (see Table 2.6). Factors affecting the chemical composition of Kishk may include: (a) the use of different ratios of fermented milk to cereals, (b) replacement of Burghol with Chick-pea and/or soy bean flour, (c) no cereal is added to fermented milk, (d) use of Labneh rather than low solids fermented milk, and (e) different fat contents in the fermented milk used. Other factors which may influence the composition reported by Jandal (1989) and Tamime and O'Connor (1995) are summarised as:-

- Proteolysis and carbohydrate metabolism by micro organisms,
- Inherent differences between the traditional methods of manufacture,
- Different proportions of Burghol, fermented milk and salt,
- The use of different multiplication factors (6.25 or 6.38) for nitrogen conversion to calculate the protein content in the product,
- The data being expressed either as a percentage on wet- or dry-weight basis and
- Different drying techniques used for manufacturing of the product.

Recently, Tamime (unpublished data) reported the range of composition (g 100 g^{-1} dry weight basis) of commercial Lebanese Kishks in between 6.8 and 1.8 for moisture, 14.7 and 21.4 for protein, 2.6 and 11.5 for fat, 61.0 and 76.8 for carbohydrates, and 4.1 and 9.3 for ash. The author attributed the variations to the different levels of yoghurt and Burghol used during the preparation.

2.3.2 Mineral contents

Kishk is a good source of minerals, and Table 2.7 illustrates some examples. The phosphorus content in Kishk (commercial and laboratory-made) is appreciable, but lower when compared to Madeer which was made completely from milk; the calcium and magnesium contents were generally low with the exception of Lebanese Kishk (Tamime and O'Connor, 1995). Recently, 25 commercial Lebanese Kishks were investigated, and

Table 2.6 Range of chemical composition (g 100 g^{-1}) of commercial, laboratory-made Kishk and related products.

Product	Moisture	Protein	Fat	Carbohydrate	Fibre	Ash
Commercial	3.9-13.0	8.9-54.4	1.6-19.9	31.0-65.7	.05-2.5	2.0-11.6
Laboratory-made						
Fermented milk and Burghol	5.2-9.5	14.6-19.7	11.1	—	—	—
Fermented milk and flour (wheat, rice, chick-pea and/or maize)	5.2-13.0	16.7-25.8	0.7-4.5	56.3-70.6	0.8-2.7	2.3-9.9
Fermented milk +/or soy milk and Burghol, flour (wheat, chick-pea)	5.2-9.9	16.1-28.2	—[NR]	—	—	3.5-5.3
Fermented whey and Burghol	9.7	13.3	—	—	—	—
Madeer and Oggt	3.5-8.3	26.3-40.5	8.8-41.1	20.2-48.7	—	5.3-8.3

Data adapted from Tamime and O'Connor (1995).

[NR] Not reported.

Table 2.7 Range of mineral contents (mg 100 g^{-1}) of Kishk and related products.

Constituents	Commercial	Laboratory-made	Madeer
Phosphorus	242.0-410.0	359.0-375.0	957.0
Calcium	38.0-600.0	78.0-134.0	982.0
Iron	2.3-3.9	3.1-14.5	2.5
Magnesium	3.1	53.8-116.1	141.0
Manganese	—[NR]	1.0-4.1	0.1

Data adapted from Tamime and O'Connor (1995).

[NR] Not reported.

the major elements (K, P, Ca and Mg) were found in appreciable quantities; the Na content was high due to the added salt (Tamime, unpublished data). The same author reported that Kishks made with Burghol contained higher quantities of Fe and Mn when compared with dairy products or milk products. However, the concentration of iron in Kishk was increased significantly when it was made with soy milk and chick-pea flour (Hassan and Hussein, 1987) because such products are good sources of iron.

2.3.3 Vitamins

Kishk contains significant amounts of certain B vitamins, but it is deficient in vitamin C and some fat-soluble vitamins. However, niacin is the only vitamin which was higher in concentration when compared to milk (Tamime and O'Connor, 1995). This was due to the activity of micro-organisms during the fermentation of milk (Reddy *et al.*, 1976), and Burghol contains an appreciable amount of niacin. According to van Veen *et al.* (1969), the Kishk made with tomato juice gave improved flavour and taste and contained higher amounts of riboflavin and pro-vitamin A. However, Tamime (unpublished data) reported that Kishk is deficient in certain vitamins, and it is not considered a good dietary source.

2.3.4 Amino acids

Kishk contains high amounts of essential amino acids (see Table 2.8) *i.e.* phenylalanine, threonine, isoleucine, leucine, valine, tyrosine and lysine, but not tryptophan and histidine (Tamime and O'Connor, 1995). This may be due to the decomposition of tryptophan during fermentation of the mixture or sun drying (Morcos *et al.*, 1973). Cadena and Robinson (1979) reported the amino-acid spectrum of Kishk close to the FAO/WHO standards with the exception of lysine and threonine which were in limiting values.

2.3.5 Fatty acids

The fatty acid composition of lipids has received considerable attention with respect of the risk to coronary heart disease (CHD) which is attributed to chain length, degree and position (n-3, n-6, n-9) of unsaturation, geometric configuration (cis, trans) and sn position

Table 2.8 Essential amino acid contents (mg g^{-1} protein) of Kishk and related products.

Products	Histidine	Isoleucine	Leucine	Lysine	Methionine	Cystine	Phenylalanine	Tyrosine	Threonine	Tryptophan	Valine
Kishk											
Lebanese	10.44	17.00	32.00	20.25	7.56	6.69	19.63	16.31	12.81	3.81	20.38
Eygptain	9.69	65.67[a]		19.38	7.50	6.88	19.38	15.94	13.75	4.06	20.94
Skimmed milk	10.74	11.17	33.05	21.17	10.35	11.48	9.34	14.77	15.78	–[d]	13.63
Rayeb	13.01	11.09	25.31	23.20	13.59	10.70	6.45	17.15	12.93	–	13.67
Trahana											
Traditional	11.00	14.69	29.06	18.75	7.00	1.06	18.69	10.88	9.31	3.63	14.86
Commercial	9.00	13.94	27.56	17.13	7.19	0.88	18.00	11.69	11.50	3.81	15.19
Madeer	10.06	18.63	38.94	27.75	11.00	3.36	19.63	16.69	21.50	4.63	26.89
FAO/WHO/UNU suggested pattern	16.00	13.00	19.00	16.00	17.00[b]		19.00[c]		9.00	5.00	13.00

Data compiled from Salama *et al.* (1992) and Tamime and O'Connor (1995).

[a] Values for Isoleucine and leucine.

[b] Values for methionine and cystine.

[c] Values for phenylalanine and tyrosine.

[d] Not reported.

(Nawar, 1996). However, Tamime (unpublished data) reported that Lebanese Kishk contained appreciable quantities of poly-unsaturated fatty acids, and the mono-unsaturated acids were considerably lower than those present in milk and other dairy products. It could be argued, therefore, that the fat content of Kishk is inherently low and the risk of heart disease associated with this product should be low.

2.3.6 Miscellaneous carbohydrate components

The carbohydrate-based contents (dietary fibre and β-glucan) have been recognised as desirable food components. The dietary fibre is claimed to decrease blood cholesterol levels, lessening the chance of heart diseases and reducing the chance of colonic cancer, while the β-glucans reduce postprandial serum glucose levels, insulin response, and cholesterol concentration in the blood (BeMiller and Whistler, 1996).

In spite of the fact that these carbohydrate-based contents are desirable food components, the phytic acid in cereals is considered as an anti-nutritious component. Thus, the acid forms insoluble complexes with minerals such as Ca, Fe, Mn, Zn and possibly reduces their bioavailablity (Kent and Evers, 1994). However, this anti-nutritious factor can be broken down by microbial phytase activity (Huis in't Veld *et al.*, 1990). Lebanese Kishks have concentrations of dietary fibre, β-glucan and phytic acids (g 100 g^{-1} on dry matter basis) that range between 7 and 12, 0.1 and 0.6, and 0.7 and 1.6, respectively (Tamime, unpublished data).

2.3.7 Organic acids

The concentration of individual organic acids in food may be nutritionally significant. These are normally constituents of metabolic pathways and can provide energy to the body (Paul and Southgate, 1978). During Kishk-making, six organic acids (butyric, propionic, acetic, formic, lactic, succinic acids) were reported by Damir *et al.* (1992) to be present, while Salama *et al.* (1992) observed that Kishk made with milk rayeb had a higher concentration of organic acids than the product made with skimmed milk. After preparing the Kishk as a 'dish', the percentage of butyric, propionic, lactic and succinic acids decreased, but acetic and formic acids totally disappeared.

2.4 Microbiological Quality of Kishk

Brock *et al.* (1994) classified foods, in term of microbial spoilage, into three major categories:-

- Highly perishable foods such as meats, fish, eggs, milk, and most fruit and vegetables;
- Semi perishable foods such as potatoes, some apples, and nuts; and
- Stable or non-perishable foods such as sugar, flour, rice and dry beans.

Microbial activity can be controlled by heating, lowering the water activity and pH, and/or the addition of salt. Kishk can be considered as a stable or non-perishable food product because it is acidic in nature, contains low moisture and salt. The major organic acid present in Kishk is lactic acid which is the result of the metabolic activity of the starter culture. No coliforms or *Staphylococcus aureus* were reported in commercial and laboratory-made Kishks (Tamime and O'Connor, 1995). However, faecal enterococci were reported in 1 out of 8 samples of Kishk tested (Atia and Khattab, 1985), which could be attributed to the product bring high in pH and low in salt.

The total colony counts of Kishk samples varied widely from 2.9×10^3 to 1.1×10^6 cfu g^{-1} while the spore-formers varied from 57.1 to 75% of the total count and were dominant in the product. Among the spore-formers identified, *Bacillus licheniformis*, *Bacillus subtilis* and *Bacillus megatherium* were the most dominant; other organisms including lactic acid bacteria accounted for 20.9 and 42.9% of the total bacterial flora (El-Sadek and Mahmoud, 1958; El-Gendy, 1983, 1986).

The mean counts (cfu g^{-1}) of total mesophilic bacteria, proteolytic bacteria, yeasts and moulds, staphlococci and micrococci in Kishk were 4.84×10^6, 3.98×10^6, 1.05×10^3, 1.55×10^4, and 3.89×10^6, respectively. Dominant colonies were identified as *B. subtilis*, *Bacillus polymyxa*, *Bacillus coagulans* and *Bacillus cereus*. The high atmospheric temperature and direct sun light used for drying the Kishk may be responsible for the high incidence of spore-formers (Atia and Khattab, 1985).

2.5 Organoleptic Evaluation of Kishk

Sensory properties can be measured by the degree of disparity between expected and perceived product performance. According to Cardello (1993), the expectation may be distinguished in two ways: *firstly*, factors that may affect the perception of sensory attributes which may lead the consumer to believe that the product will possess certain characteristics (*e.g.* a sensory-based expectation), and *secondly*, factors that may relate to like/dislike to a certain degree (*e.g.* a hedonic expectation).

In past, Kishk has been evaluated by both of these methods, and this could be due to the use of different ingredients and/or the related methods used to prepare the Kishk as dish. The different sensory methods used by Hafez and Hamada (1984), Al-Ruqaie *et al.* (1987), Hassan and Hussein (1987), Al- Mohizea *et al.* (1988) and Abou-Donia *et al.* (1991) are summarised below:-

- Nine-point Hedonic rating scale (9 = like extremely to 1 = dislike extremely).
- Five-point Hedonic scale.
- Acceptability, flavour, sourness, general appearance, colour and texture.
- Nine-point Hedonic scale (colour, odour, taste, texture, and overall acceptability).
- Flavour, body and texture, appearance and acidity.

Al-Mohizea *et al.* (1988) evaluated Oggtt and found that the product made from cow's milk was superior to that made from sheep's milk, while the same product made from goat's, cow's or reconstituted skimmed milk powder was acceptable to the panellists. However, flavoured Oggtt (chocolates, coffee, mint, orange, pineapple, or strawberry) were not popular with the exception of 'date' flavour (Al-Ruqaie, 1987). Damir *et al.* (1992) reported that the sensory properties of Kishk in soups made from cultured skimmed Laben Rayeb had better flavour when compared with similar product made with whole milk Laben Rayeb.

Salama *et al.* (1992) observed no significant differences in analysis of variance between the Laban Rayeb and skimmed milk cooked Kishks in terms of colour and consistency; however, the skimmed milk product scored better for flavour while the Laban Rayeb Kishk had a stronger acidic taste. Kishk reconstituted with hot water had a pleasant taste, malty flavour, and a consistency (variable according to personal taste) that was smooth on the palate (Robinson, 1978).

Cadena and Robinson (1979) reported that a typical Mexican food (*i.e.* Atole a gruel food) made by substituting the maize flour with a yoghurt-like product was readily accepted by Mexican mothers and children. Flavoured gruel, especially strawberry and vanilla proved most popular. Hassan and Hussein (1987) investigated that addition of soy milk to replace cow's milk or using a mixture of soy milk and skimmed milk in the production of Kishk from Burghol or chick-pea; such products were more acceptable, and had a better taste, odour, appearance and colour than the control. Abou-Donia *et al.* (1991) reported that Kishk made with whole wheat flour, rice flour and maize flour were highly accepted by the taste panellists. However, the rice flour Kishk was awarded the highest score by the judges.

Recently, Muir *et al.* (1995) have developed a sensory profile for the evaluation of Kishk by trained panellists which might be helpful for the industrial Kishk production in the future. The profile of sensory attributes were aroma (*overall intensity, creamy/milky, acid/vinegary/sharp, fruity/sweet, cooked, cereal, cardboard*), flavour (*overall intensity, creamy/milky, acid/vinegary/sharp, fruity/sweet, cooked,, cereal, cardboard, apple, bitter, salty*), after-taste (*overall intensity, persistence, acid/vinegary/sharp, cereal, cardboard*) and mouth feel (*viscosity, grainy/floury chalky texture, sticky/gluey texture, slimy texture, mouth-coating*). These attributes were used to assess fifteen Kishk samples purchased from different granaries, dairies, and supermarkets in the Lebanon and compared with two traditional Scottish oat meal porridges. Substantial differences were found between the samples, and many of the Kishk samples were rated highly for bitterness and for cardboard character which are disliked by consumers in the UK.

2.6 Future Trends, Health and Development of Kishk

2.6.1 Introduction

The current trend in consumer life-styles and modifications in the eating habits for health reasons has had to a demand for new products throughout Europe and North America. Products like fermented milk, yoghurt, yoghurt-related products and other products containing milk have been found acceptable by the consumers because of their nutritional and healthy image. However, whole cereal grains have re-acquired popularity due to their desirable food components like dietary fibre. A diet which contains sufficient fibre content may reduce the incidence of diseases of the alimentary tract, such as diverticular disease, cancer of the colon and haemorrhoids (Gaman and Sherrington, 1990), and a considerable reduction in blood cholesterol level (Kent and Evers, 1994). Various soluble fibres (*e.g.* β-glucan, gums, pectin) can lower the low-density lipoprotein levels in the blood and elevate levels of high-density lipoprotein (Pomeranz, 1991).

Taking into account to the nutritional image of fermented milk products coupled with cereals, Kishk could be beneficial product for meeting these criteria. However, a clear difference was found between the sensory characters of 15 varieties of commercial Kishk samples made from wheat Burghol and yoghurt made from cow's or goat's milk (Muir *et al.*, 1995). These differences could be attributed to some of the factors described by Tamime and O'Connor (1995). In fact, there will be a need to standardise the manufacturing stages of Kishk in order to meet the current consumer demand. To achieve this goal, yoghurt and added cereals of known chemical composition should be used. Thus, the product will contain a balance of nutrients originating from milk and cereals. Also the sanitary condition during production should not be overlooked. For the purpose of this investigation it was decided to use skimmed milk powder (SMP) and anhydrous milk fat (AMF) rather than raw milk in order to minimise the seasonal variation that may occur in the milk. Likewise, the cereal component(s), which may play important part in Kishk-making, has to be examined, but little is known about their contribution to the overall quality of the product.

2.6.2 Oat (*Avena sativa*)

The gross physical structure of the oat groat is similar to that of the kernel of wheat. Compared to other cereals, oat groats are characterised by a low carbohydrate content and a higher protein and fat content. Oats are widely used in Scotland, such as oat meal, oat flour, natural cereals, meat product extenders, cookies and breads, granolas, and baby foods, but the main consumption is as a breakfast cereals and snacks (Bahl, 1996). Oats have indeed a favourable nutritional composition (Lockhart and Hurt, 1986; Frölich and Nyman, 1988), and one unique feature is the outstanding high content of polar lipids (phospholipids and glacto-lipids) which can exercise a protective effect on the mucosa layers (Dunjiĉ, 1993). Both the oat fibre and β-glucan have been shown to reduce the level of serum lipoprotein and serum cholesterol (Swain *et al.*, 1990; BeMiller and Whistler, 1996). Huchtiston and Cook (1988) have examined the opportunity for alternative uses of oats and oats-based products, for example, as an addition or alternative to wheat flour in baking cakes, biscuits, and snacks, either blended down to oat flour or as a whole (MacCarthy, 1988).

Oats can be considered a fairly good source of Mn, Mg, I, Ca, Zn and Cu. The phosphorus content also appears fairly high, but the bioavailablity of this element has been called into question by some nutritionists because of the relatively inert form (phytic acid) in which it exists in oats (Matz, 1991). Oats and oats-based products contribute a small but significant amount of vitamins to the human diet (Lockhart and Hurt, 1986), but it is a good source of thiamine and panthionic acid.

2.6.3 Barley (*Hordeum vulgare*)

Barley is one of the world's oldest domesticated crops and competes with wheat. The structure of a typical hulled barley kernel from the outside inward is composed of lemma and palea enclosing and cemented to the caryopses (Matz, 1991). The chemical composition and properties of barley as a food grain were reviewed by Newman and Newman (1991). Barley has been used in snacks, breakfast cereals, baby foods, cookies, breads, and cereal yoghurts (Sparrow *et al.*, 1989). However, in the Far East and Middle

Eastern countries barley is consumed as pearled grain in soups, as flour for making flat-type bread, and ground grain to be cooked and eaten as porridge (Kent and Evers, 1994).

2.6.4 Porridge oats (Rolled oats)

Rolled oats are made from coarse groats after crushing them in flaking rollers (Bahl, 1996). They are partially cooked during manufacture where the pinhead oats meal from which the rolled oats are made is softened using steam and, in this plastic condition, is flattened on flaking rolls (Kent and Evers, 1994). The nutritive value of rolled oats when compared with the raw materials from which it was made depends very much on the processing treatment involved. The chemical composition of rolled oats is shown in Table 2.3.

2.7 Conclusion

The use of different cereals could be useful to evaluate the acceptability of Kishk made from these cereals. In order to evaluate and standardise this traditional product, a research work has been initiated to study Kishk. The overall objectives of this study were to produce and standardise the laboratory-made Kishk modifying the manufacturing stages and replacing the Burghol with other cereals (*i.e.* different varieties of oats and barley). Also strategically investigating the possible changes and/or interactions occurring during the secondary fermentation stage.

CHAPTER THREE:

EXPERIMENTAL MATERIALS AND METHODS

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3.1 Raw Materials

3.1.1 Skimmed milk powder (SMP)

Skimmed milk powder of the required quality was used throughout this study. The powder was obtained from Dairy Crest Ingredients, Surrey, UK, in 25 kg bags and stored in a cold and dry place (< 10°C).

3.1.2 Anhydrous milkfat (AMF)

Anhydrous milkfat was used to standardise the milk base, and was obtained from Bodfari Producers Ltd., Chester, UK. The AMF was received in packages of 25 kg and stored -20 ± 2°C.

3.1.3 Starter culture

Pure, freeze-dried commercial yoghurt starter culture MY 087 (*Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus*) was obtained from Rhône-Poulenc Texel (UK) Ltd., Cheshire, UK and used for ferment the milk base. It was stored at -40°C until required, and was used for direct-to-vat inoculation (DVI) at rate of 1.9 g 10 kg^{-1} for the production of low-fat yoghurt.

3.1.4 D-Glucono-δ-lactone (GDL)

A food grade D-Glucono-δ-lactone was used to acidify the milk to pH ~ 4.5. The GDL was obtained from Peter Whiting (Chemicals) Ltd., London, UK in 25 kg bags and stored in cold place.

3.1.5 Oat and barley

Four varieties of oat [Adamo and Matra (early spring sown), Dula and Valiant (late spring sown)] and four varieties of non-waxy barley [Pastoral and Marinka (winter sown), Maghee and Camargue (spring sown)] were used for preparing Burghol. The barley and oats were obtained from Alexander Barley Seeds, Milnathort, Scotland, UK.

3.1.6 Porridge oats (rolled-oat) and oat meal flour

Two batches each of pure Scottish rolled-oats and oat meal flours were used for the production of laboratory-scale Kishk. These were obtained from Grampian Oat Products, Boyndie, Scotland, UK in 25 kg bags. The bags were stored in a dry and cool place.

3.1.7 Wheat Burghol

Three batches of wheat Burghols, of which one batch was in two fractions (*i.e.* coarse and fine) and other two were coarse, were obtained from Najar Granary Ltd., and Shoubasi Trading, Chtoura, Bekka Valley, Lebanon. Both fractions were used for chemical analysis, while for Kishk-making only the coarse fractions were used.

3.1.8 Wheat flour

Two batches of wheat (each of 10 kg) were purchased from Najar Granary Ltd. and Shoubasi Trading, Bekka Valley, Lebanon. The grains were first sieved using laboratory-sieves to remove the dust and husks, and later refined by hand to clean of stalks and weed seeds. The cleaned grains were milled using a Buhler MLU-202 Laboratory mill at Weston Research Laboratories Ltd., Berkshire, UK. A flow diagram outlining the main stages of wheat milling is shown in Figure 3.1. Seventy percent extracted flours were used for Kishk-making.

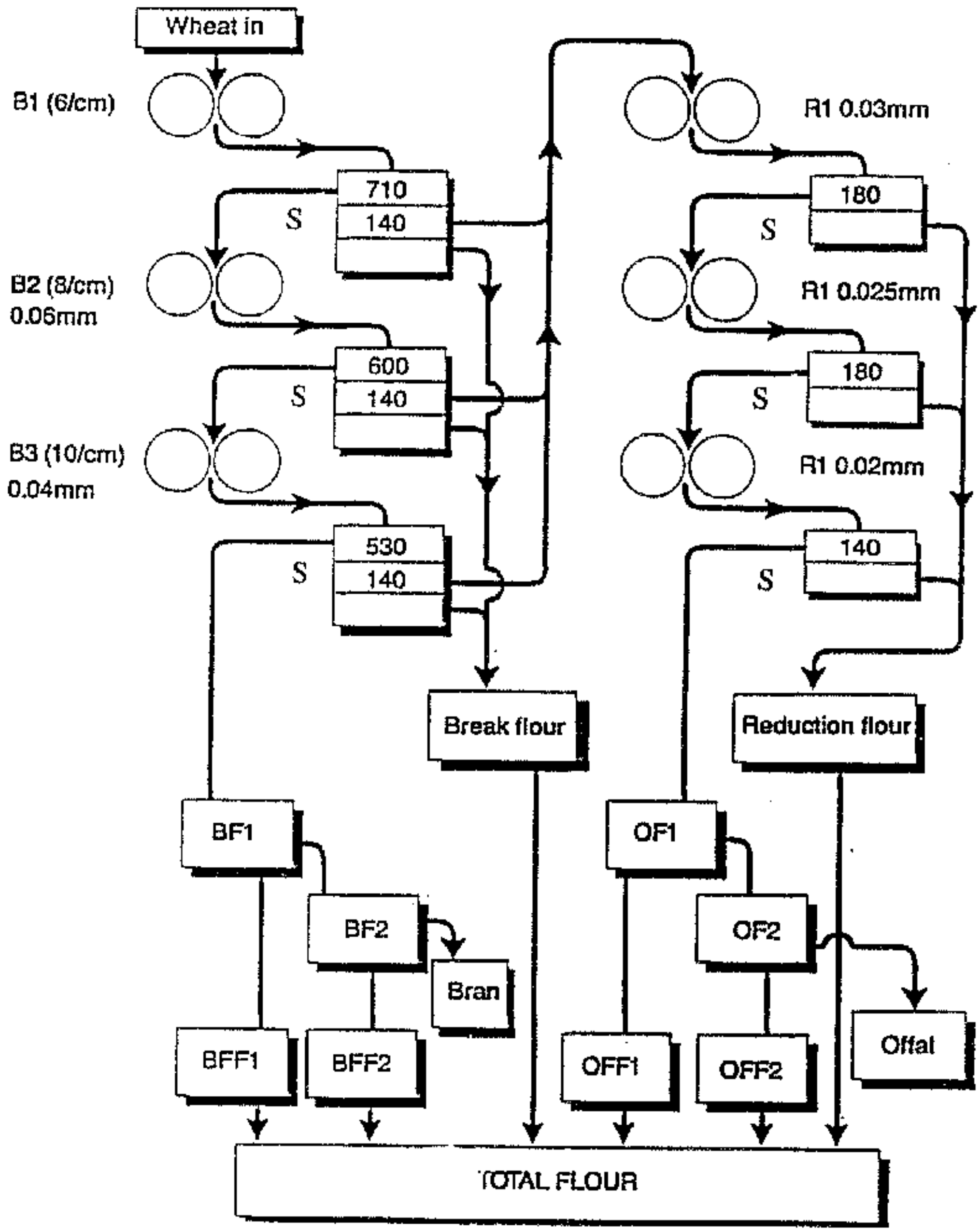


Figure 3.1 Flow diagram outline the main stages of wheat milling.

B: Break. R: Reduction. S: Sifters; all the sifters are in microns. OO: Break and reduction rolls. 0.0x mm: Roll gap. (x/cm): Flutes. 1, 2, 3: B or R, grinding or sifting stages. BF/OF: Bran/Offal finisher. BFF/OFF: Bran/Offal finisher flour. Total flour: The blend of straight-run and finisher flours. Bran: Overtails of the break system. Offal: Overtails of the reduction system.

3.1.9 Wheat Burghol flour

Two batches of wheat Burghol (see section 3.1.7) were milled to obtain flour using a laboratory hammer mill and 0.8 mm sieve. These flours were used also for Kishk-making.

3.2 Processing Equipment and Utensils

3.2.1 Ohaus and Avery Scales

Scales model IS-15 (Ohaus Corporation, Florham Park, USA) capacity 15 kg x 0.001 kg, and type 1303 BDL (W. & T. Avery Ltd., Birmingham, UK) were used to measure the SMP, AMP and water for the preparation of the milk base, yoghurt and cereals for Kishk-making.

3.2.2 Miscellaneous utensils

Aluminium milk cans (~ 40 kg capacity) were used to prepare the milk base and yoghurt. Stainless steel buckets, hand whisk and plungers were used during the preparation of laboratory-scale Kishk. Also, stainless steel bowels were used to mix the yoghurt and cereal(s) for 6 d during the secondary fermentation stage. Stainless steel desert and tea spoons were used for making the nuggets of yoghurt/cereal mixtures after the secondary fermentation and prior to drying. Stainless steel trays were used as containers for the nuggets of yoghurt/cereal mixture during the drying period. These utensils were obtained from Coldstream Engineering Ltd., London, UK.

3.2.3 Heat treatment unit

A water tank fitted with steam injection system was used for the heat treatment of milk base.

3.2.4 Homogeniser

A homogeniser model Lab 4746/72 (Rannie Machine Works Ltd., DK-2620 Albertslund, Denmark) was used to homogenise the milk base.

3.2.5 Thermometer

A portable digital thermometer Testo 900 (Testoterm Ltd., Hampshire, UK) was used to record the temperature during different processing stages.

3.2.6 Hydrogen ion meter

A portable pH meter model `Check Mate 90´ (Mettler Toledo Ltd., Essex, UK) fitted with standard glass electrode was used to record the pH values of the milk base before and during the fermentation, and of the yoghurt before mixing with cereals. The equipment was calibrated with standard buffer solutions of pHs 7 and 4 (BDH Chemicals Ltd., Poole, UK) prior measuring the pH of sample.

3.2.7 Incubation cabinet

A thermostatically controlled incubator type P-33 A-18 (LEEC Electrical Engineering Ltd., Nottingham, UK) was used to ferment the milk base.

3.2.8 Laboratory sieves

Stainless steel laboratory sieves (BS 410/1986) with apertures of 1.0, 1.4 and 2.00 mm manufactured by Endecotts Ltd., London, UK, were used to size the different types of Burghol and/or flour.

3.2.9 Laminar flow cabinet

M.D.H (Inter Med) Laminar flow cabinet (Microflow Pathfinder Ltd., Fleet, UK) fitted with high efficiency filter to sterilise the air was used for the secondary fermentation of yoghurt/cereal mixtures.

3.2.10 Baking oven

A single revorack gas baking oven (Double D Food Engineering, West Lothian, UK) fitted with a single bay tray trolley (*i.e.* capacity of 16 trays) was used to dry the yoghurt/cereal mixture.

3.2.11 Laboratory hammer mill

A laboratory hammer mill (Christy Noris Ltd., Chelmsford, UK) was used to grind the dried yoghurt/cereal mixture. It was also used for milling the Burghol into flour.

3.2.12 Plastic bags

Plastic bags (Park Packaging Ltd., Glasgow, UK) were used to store the Kishk until required for testing.

3.2.13 Heat sealing machine

A heat sealing machine (Audion Great Britain, A.I. Packaging Ltd., London, UK) was used to seal the plastic bags containing the Kishk.

3.2.14 Plastic containers

Sterile plastic containers (100 ml) with plastic cap (Bibby Sterlin Ltd., Stone, UK) and jars (300 ml) (Medfor Products, Farnborough, Hants, UK) were used to store the Kishk samples for microbiological and chemical analysis, respectively.

3.3 Production of Kishk

3.3.1 Production of low-fat yoghurt (using yoghurt starter culture)

The yoghurt was prepared according to the method reported by Barrantes (1993) with slight modification. A flow diagram for the preparation of yoghurt is shown in Figure 3.2. The skimmed milk powder (SMP) was reconstituted to ~11 g 100 g^{-1} total solids at 40°C and then warmed to 60°C. The melted AMF at 65°C was added at a rate of ~1.5 g 100 g^{-1} to the reconstituted skimmed milk. The milk base was homogenised at 17.3 MPa pressure and heated to 90°C for 10 min using the water tank fitted with the steam injection system. It was then cooled to 45°C by circulating mains water. The treated milk base was inoculated with yoghurt starter culture (MY 087) as direct-to-vat at a rate of 1.9 g 10 kg^{-1} and incubated for ~ 4-5 h at 42°C or pH 4.6. The fermented milk was then transferred to a cold store at ~ 5°C.

3.3.2 Production of low-fat yoghurt (using GDL)

The yoghurt was prepared in a similar manner as mentioned in section 3.3.1 except GDL was used at a rate of 2 g 100 g^{-1} to acidify the milk base for ~ 2-4 h at 42°C or to pH 4.5.

3.3.3 Production of Burghol

The traditional method for the preparation of wheat Burghol in Lebanon was described by Tamime and O'Connor (1995) (see also Table 2.4). In brief, the manufacturing stages used for Burghol production are shown in Figure 3.3. Traditionally, the Burghol is separated from the bran by winnowing (Figure 3.4). However, under commercial operations a mechanised and enclosed winnowing machine made locally from wood (1.5 x 2 - 2.5 x 1.5 m) is used (Tamime and O'Connor, 1995). Figure 3.5 illustrates schematically the separation of bran from the Burghol by using density fractionation.

The Burghol of oat and barley varieties (section 3.1.5) each of ~15 kg were prepared in Lebanon in a similar fashion to the method described in Figure 3.3 (see also Tamime and

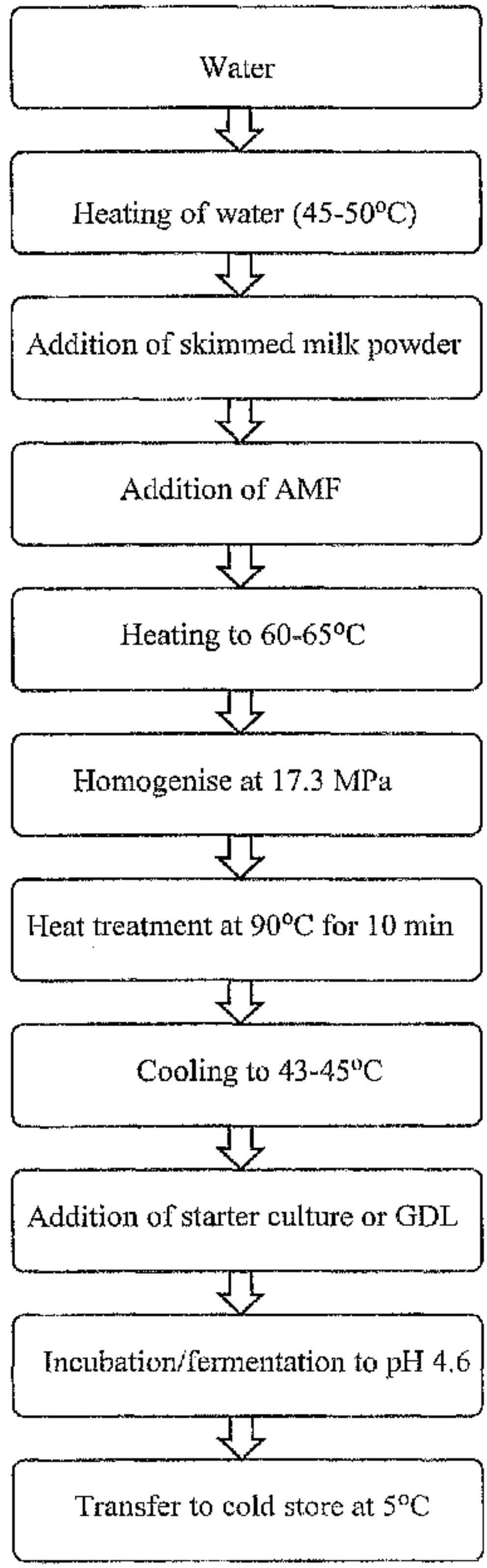


Figure 3.2 Flow diagram for the preparation of yoghurt and/or acidified milk.

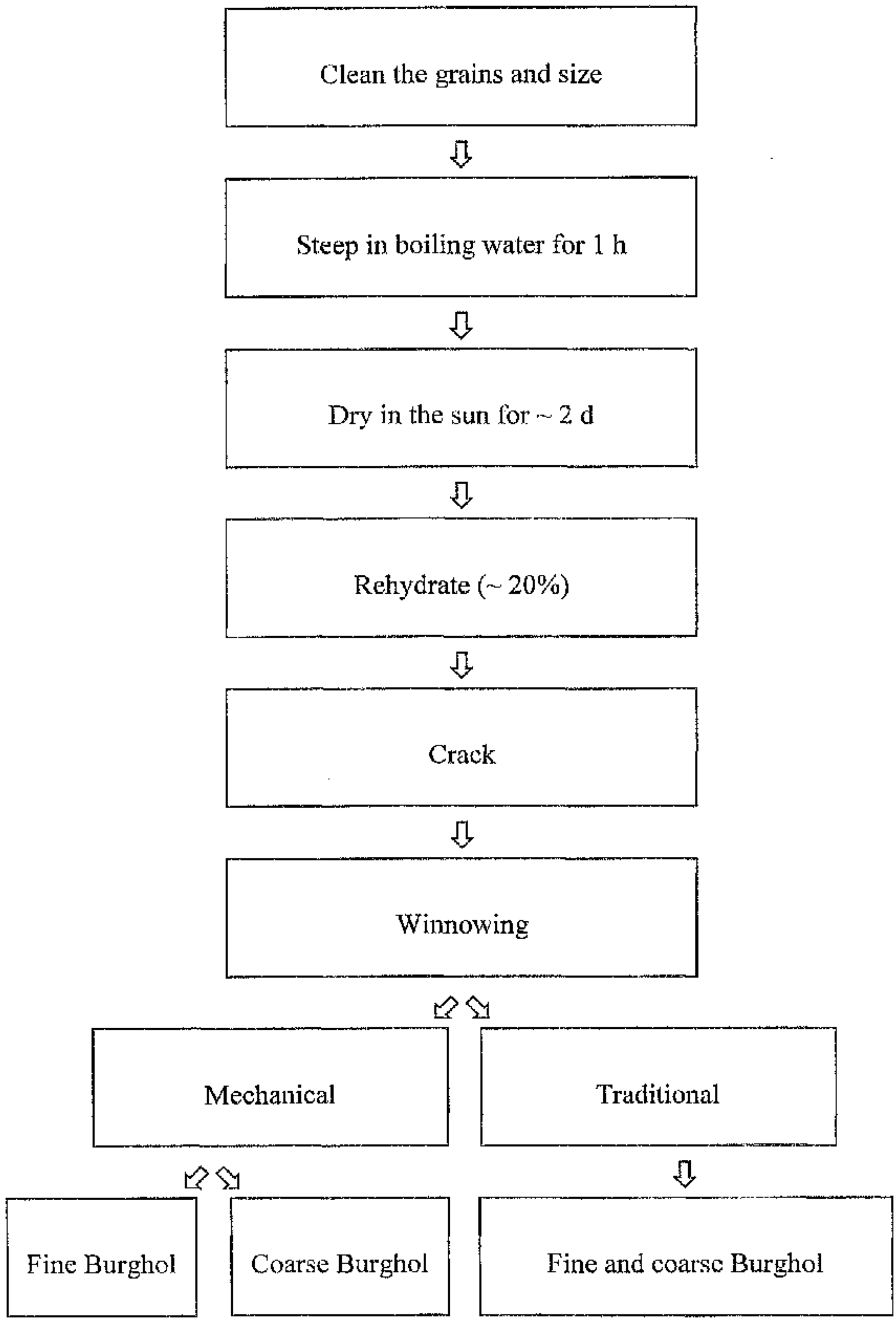


Figure 3.3 Manufacturing stages for the production of Burghol.

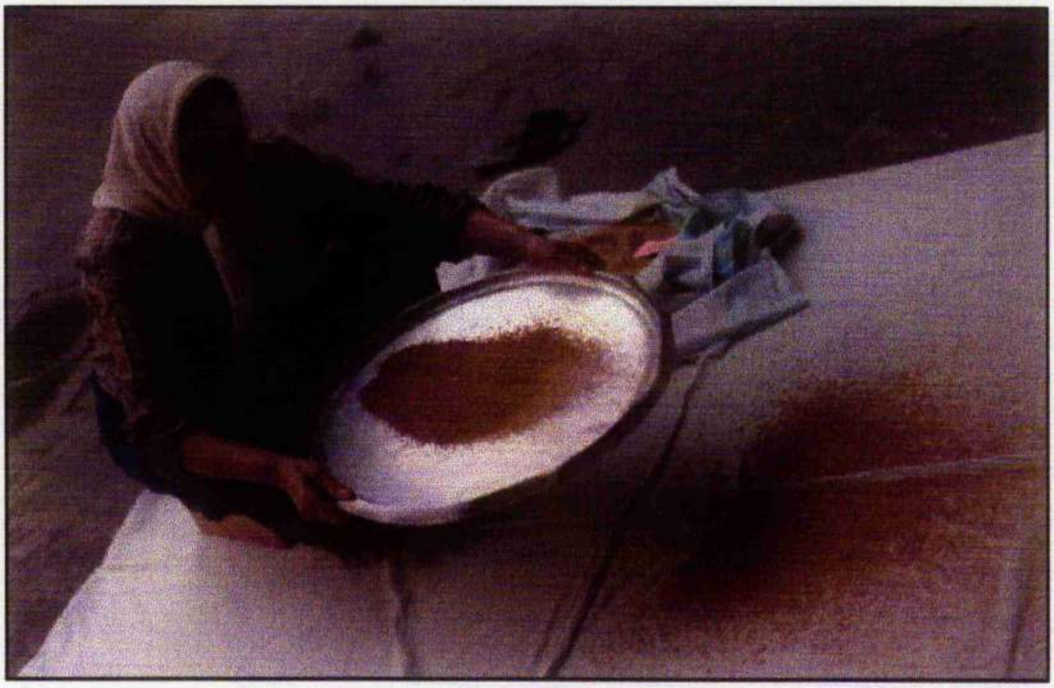


Figure 3.4 Illustration of traditional winnowing technique to separate the husk from the cracked wheat grains.

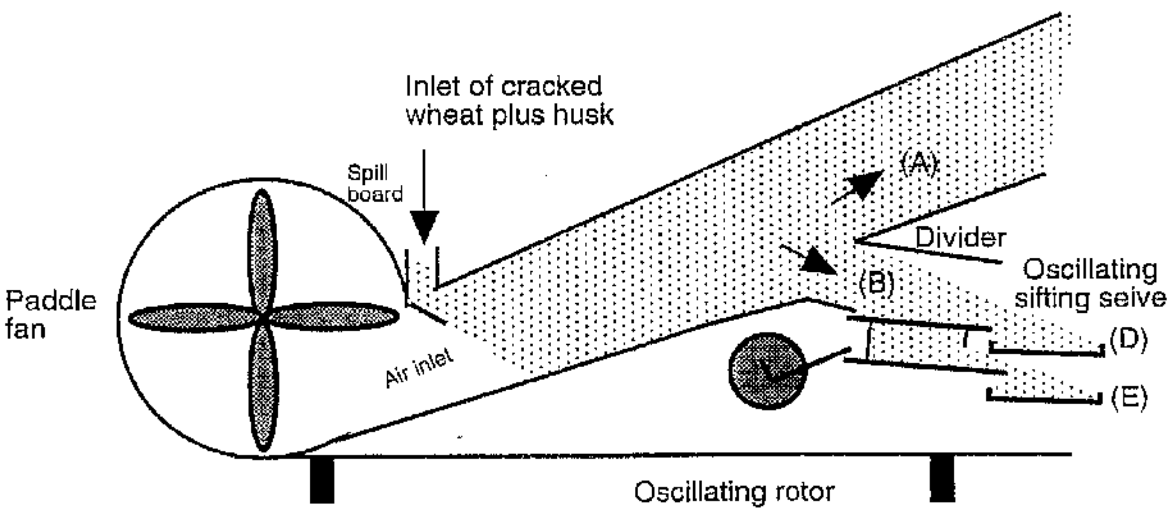


Figure 3.5 Schematic illustration of a mechanically winnowing machine made locally in Lebanon.

(A): Low density fraction husk. (B): High density fraction (Cracked wheat).

(D) & (E): Collecting drawers for coarse and fine cracked wheat, respectively.

O'Connor, 1995) because the cracking machine was not available in the laboratory. The grains were first cleaned by hand instead of using the `ghorbal' because the commercial machines were too large to handle such a small quantity. The grains were soaked in boiling water for ~ 1 h and then left for drying in the sun for ~ 2 d. The parboiled dried grains were moistened with ~ 20% water, cracked and sun dried. After cracking, the husk was removed in Scotland for the following reasons:

- The traditional winnowing method was ineffective as the lemma and palea fractions were heavy when compared with the cracked grains, and
- The Lebanese commercial winnowing machines were too large to handle the experimental samples.

In Scotland, husk separation from oats and barley was difficult. Several fractions were obtained from each cracked sample using a Dockage Tester, which uses sieves and air for cleaning (Loaned from Rank Hovis, McDougall Research and Engineering Ltd., The Lord Rank Centre, Lincoln Road, High Wycombe, UK).

Before Kishk-making, each type of Burghol mentioned in the sections 3.1.7 and 3.3.3 was first refined by hand and also using Laboratory sieves. Later the Burghol was washed with water ~ 50°C in order to remove any pieces of husk, residual bran or flour dust. The Burghol was then dried at ~50°C to approximately the same moisture content.

3.3.4 The manufacturing stages of Kishk

Laboratory-made Kishks were produced using four varieties each of oats and barley and one variety of wheat. An outline of the manufacturing stages of Kishk is illustrated in Figure 3.6. Four parts of low-fat yoghurt (section 3.3.1) are mixed with salt at a rate of 0.75-1.00 g 100 g^{-1} and with one part of Burghol added on three consecutive days. The dough-like mixture was kneaded twice daily and fermented for six days at 20-25°C. Then the mixture was shaped into nuggets (3-5 cm in diameter), placed onto the stainless steel trays and dried at ~50°C for 8-10 h in a bakery oven. The dried Kishks were ground to powder using a laboratory hammer mill with mesh size sieve of 0.8 mm. The products were packed into plastic bags, sealed with a heat-sealing machine and then stored in the

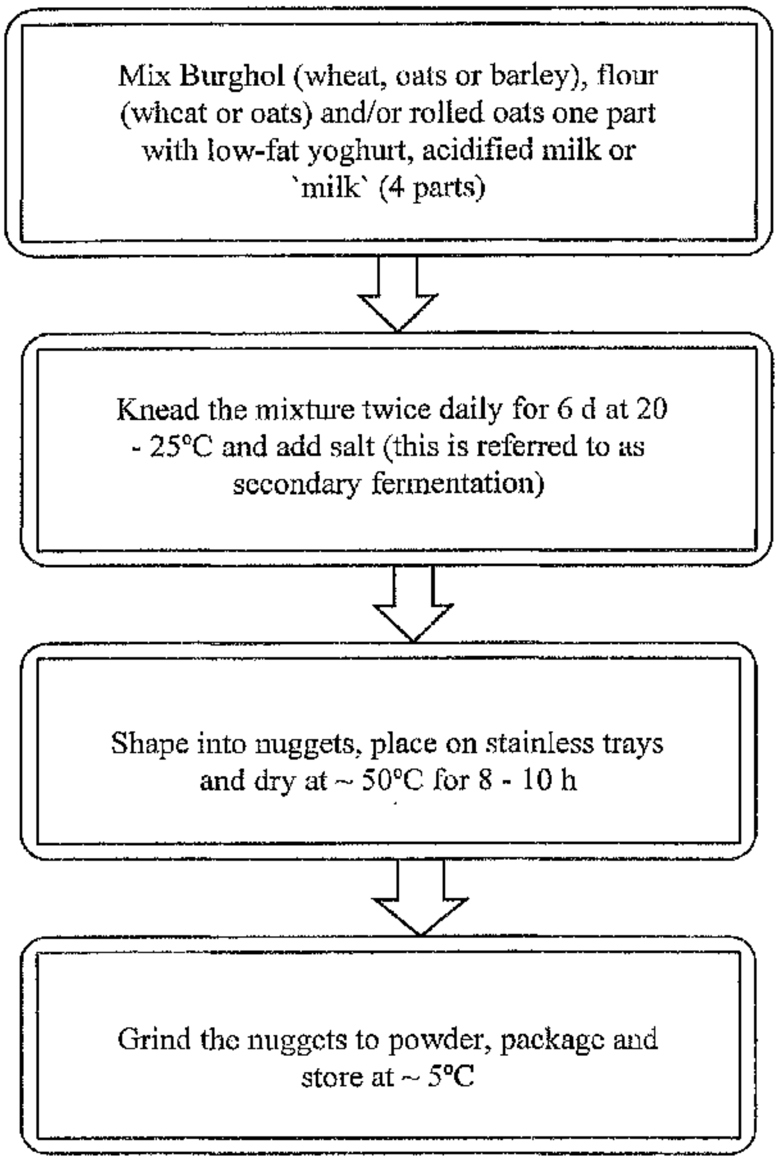


Figure 3.6 A schematic illustration for the production of Kishk.

cold store until required for analysis and assessments.

In a separate experiment, Kishks were produced in a similar manner as shown in Figure 3.6 using two different batches each of porridge oats (rolled oat), oat meal flour, wheat Burghol and wheat flour. The processed milk was divided into three equal portions. In the first batch, the milk was mixed with each type of cereal or flour and dried to produce non-fermented Kishk. In the second and third batches, the milks were acidified with GDL and yoghurt starter culture, respectively, for the manufacture of Kishk as shown in Figure 3.6. However, Kishks made with oat and wheat flours were thin in consistency, and as a consequence each mixture was first spread over a stainless steel tray, dried to decrease the moisture content, and then shaped into nuggets and dried as illustrated in Figure 3.6.

Also, Kishk was produced as described in Figure 3.6 using two batches each of wheat Burghol, wheat Burghol flour or wheat flour. Incidentally, the Burghol flour was made from the same batch of Burghol used for Kishk-making.

3.4 Chemical and Microbiological Analysis of Skimmed Milk Powder (SMP)

3.4.1 Determination of fat

Fat content of SMP was determined according to the method of the International Dairy Federation (IDF) (1987) which is based on the Rose-Gottlieb analytical method.

3.4.2 Determination of total nitrogen

The modified Kjeldahl method of the British Standards Institution (BSI) (1990) was used to determine the total nitrogen content of SMP. Kjeldahl catalyst tablets supplied by BDH Chemicals Ltd. were used instead of mercuric oxide. A standard solution of 1% Boric acid (containing indicator) was used as the receiving solution. After the distillation process, the ammonia was titrated with a standard solution of 0.02 N of hydrochloric acid (HCl) using a Kjeltec Auto 1030 analyser (Tecator AB, Box 70, Hoganas, Sweden).

3.4.3 Determination of total solids

The IDF (1993a) method was used to determine the moisture of the SMP. Approximately 3 g of sample was weighed on a AE balance (Mettler Instruments Ltd., Buckinghamshire, UK) and dried in an oven (Galenkamp Express, Loughborough, Leicestershire, UK) at 102°C to a constant weight .

3.4.4 Determination of ash

The ash content of the SMP was determined according to the method of BSI (1993). It was achieved by ignition of the sample at 550°C in a muffle furnace (Baired and Tatlock, London, UK).

3.4.5 Determination of titratable acidity, solubility index and scorched particles

The titratable acidity, solubility index and scorched particles of the SMP were determined according to the methods specified by the American Dry Products Institute (ADPI) (1990)- was previously known as the American Dry Milk Institute (ADMI).

3.4.6 Determination of the heat number

The heat number of the SMP was determined according to the method described by IDF (1982).

3.4.7 Antibiotics residue

The test described by Crawford and Galloway (1964) was used for the detection of antibiotics and other inhibitory in the SMP. This test detects the presence of antibiotic and other inhibitory residues at a level of 0.02 International Units (IU) of penicillum ml^{-1}. The test organism was *Bacillus stearothermophilus* var. *calidolactis*, and the disc assay was incubated at 55° C for 2 ½ h.

3.4.8 Total colony count

Plate Count agar CM 325 (Oxoid Ltd., Basingstoke, UK) was used to determine the total colony count. The pour plate method described by the ADPI (1990) was applied, and plates were incubated at 30°C for 72 h.

3.4.9 Enumeration of coliforms

Enumeration of coliforms was carried out by the method described by IDF (1985). The culture medium used was Violet red bile lactose agar CM 107 (Oxoid Ltd.). The plates were incubated at 30°C for 24 h. The confirmation test using green brilliant broth was not necessary due to the high microbiological quality of the product tested.

3.4.10 Yeasts and moulds count

The enumeration of yeasts and moulds was achieved by the method described by IDF (1990). The Yeast extract-dextrose-chloramphenicol medium consisted of 5 g yeast extract L 21 (Oxoid Ltd.), 20 g dextrose Analar grade 10117 (BDH Chemicals Ltd.), 0.1 g chloramphenicol (Sigma Chemical Ltd., Poole, UK) and 15 g agar L 11 (Oxoid Ltd.) was used. The plates were incubated at 25°C for 5 days. The added antibiotic inhibits the growth of bacterial species in the inoculated plates.

3.4.11 Thermoduric count

Plate count agar CM 325 (Oxoid Ltd.) was used to determine the count of thermoduric bacteria, following the method described by Harrigan and McCane (1976). The plates were incubated at 55° C for 48 h.

3.5 Analysis of Anhydrous MilkFat (AMF)

3.5.1 Determination of fat and moisture

The fat content of the AMF was determined by the method described in section 3.4.1. The moisture content was determined by the Karl Fischer method described by the IDF (1988a).

3.5.2 Determination of the peroxide value

The IDF (1991) method was used to determine the peroxide value of the AMF.

3.5.3 Microbiological analysis

The total colony, coliforms, yeasts and moulds, and thermoduric counts were determined according to the methods described in sections 3.4.8, 3.4.9, 3.4.10 and 3.4.11, respectively.

3.5.4 Lipolytic count

The lipolytic micro-organisms were enumerated according to the method described by Harrigan and McCane (1976). Tributyrin agar PM4 (Oxoid Ltd.) was used as a medium and the plates were incubated at 30° C for 36 h.

3.6 Enumeration of the micro-organisms in the starter culture

The freeze-dried starter culture organisms were enumerated using the method of IDF (1988b). The colonies of *Str. thermophilus* were detected using the M 17 base medium CM 785 (Oxoid Ltd.) and 10% lactose solution. The plates were incubated aerobically at 37°C for 48 h. *Lb. delbrueckii* subsp. *bulgaricus* was enumerated using MRS medium CM 361 (Oxoid Ltd.) followed by anaerobic incubation at 37°C for 72 h. An anaerobic condition was achieved by placing the plates in a GasPak ANF-402-R jar (Gallenkamp Express), and the anaerobic conditions within the jar were created using a Gas Generating Kit (a sachet contains tablets of sodium borohydride, tartaric acid and sodium bicarbonate that dissolved in water) BR 038B (Oxoid Ltd.). A blend of 10 g of starter culture in 90 ml of diluent (Quarter-strength Ringer Solution BR52, Oxoid Ltd.), and further serial dilutions (*i.e.* 1 ml of the blend into 9 ml of diluent) were prepared. The dilution levels were determined according to the manufacturer's specifications.

3.7 Analysis of organic acids of 'milk' and acidulants (yoghurt and GDL)

The method of Marsili *et al.* (1981) was used to determine the organic acids contents of the 'milk' and acidulants. A Spectra-Physics High Performance Liquid Chromatographic (HPLC) system (San Jose) was used, which was equipped with an auto sampler (Model SP 8780 XR), a detector (model LC 871 UV-VIS-PYE Unicam Ltd.) and a pump (model SP 8770 isocratic-Santa Carla, California, USA). A Chrompack (257016 cat. No 28350) ion exclusion HPLC column 300 mm long and 6.5 mm internal diameter was used. The column was provided with polymeric packing specially designed for organic acids. The column effluent was monitored at a detector wave length of 220 nm. A flow rate of solvent was 0.6 ml min^{-1} at 65°C and the pump pressure was ~ 10.07 MPa. The running time for each analysis was 30 min. The mobile phase recommended by Chrompack International, B.V., Netherlands is dilute H_2SO_4 at a concentration between 0.002 and 0.05 N. However, 0.009 N concentration of H_2SO_4 as an eluent was used.

The chromatograph was calibrated using an aqueous solution of orotic, citric, pyruvic, lactic, uric, acetic, propionic, butyric and hippuric acids (analytical grade, BDH Chemicals Ltd.) at the concentrations of 20.4, 1000, 50, 1680, 6.39, 880, 925, 1230 and 6.7 μg g^{-1}, respectively.

The test solution was prepared as follow: The sample (5 g) was mixed with 5 ml distilled water and 20 ml HPLC grade acetonitrile (BDH Chemicals Ltd.) in a 50 ml glass cylindrical tube, and the mixture was vigorously shaken. Later, it was filtered through 0.45 μm filter paper No 1 (Whatman International Ltd., Maidstone, UK). An aliquot (10 μl) of the filtrate was injected into the HPLC system and the concentration of organic acids were calculated using CHROM Perfect data processing system (Chrompack International B.V., Netherlands).

3.8 Analysis of Cereals

Different analyses on the cereals, *i.e.* oats, barley and wheat (original and parboiled grains), wheat Burghol, porridge oats and flours, were carried out and are described in the subsequent sections.

3.8.1 Chemical analysis

3.8.1.1 Determination of fat

The fat contents of the cereals were determined according to the method described by Statutory Instruments (SI) (1985) which was based on the Rose-Gottlieb gravimetric method with HCl digestion.

3.8.1.2 Determination of total nitrogen

Total nitrogen contents of the cereals (expressed as percentage of protein) were determined according to the method described in section 3.4.2. However, after completion of digestion process, the sample was distilled using 1002 Distilling Unit (Tecator AB, Box 70, Hoganas, Sweden). A standard solution of Boric acid (1g 100 g^{-1}) containing an indicator was used as a receiver solution during distillation. The ammonia trapped in acid was determined by titration with standard solution of 0.002 N HCl. The percentage of crude protein was calculated using the conversion factor of 5.83 for oat and barley, and 5.70 for wheat.

3.8.1.3 Determination of moisture

The method described by SI (1982) was used to determine the moisture content of the cereals. Around 5 g of sample was weighed on an AE balance (Mettler Instrument Ltd., Buckinghamshire, UK) and dried at 100 ± 1°C in a hot air oven (Gallenkamp Express, Loughborough, UK) to a constant weight.

3.8.1.4 Determination of ash

The ash content was estimated according to the method described in the section 3.4.4.

3.8.1.5 Determination of total carbohydrate

Total carbohydrate content of cereals was calculated by difference [*i.e.* total solids - (protein + fat + ash)].

3.8.1.6 Determination of starch

The starch was determined according to the method of SI (1982) where two separate determinations are carried out. *Firstly*, the sample was treated with warm dilute HCl [1.128% (w/v)]. After clarification (Carrez solutions I & II) and filtering, the optical rotation of the solution was measured using a polarimeter (model AA-100, Optical Activity Ltd., UK). *Secondly*, the sample was extracted with 40% ethanol. After acidifying the filtrate with HCl [25% (w/w)], clarifying (Carrez solutions I & II) and filtering, the optical rotation was also measured. The level of starch as a percentage of the sample was calculated as follow:

$$\text{Percentage of starch} = \frac{2000 \quad (P - P')}{[\alpha]_D^{20^\circ}}$$

where, P = total rotation in degrees, P′ = rotation in degrees given by substances soluble in 40% ethanol and $[\alpha]_D^{20^\circ}$ = specific rotation of pure starch (*i.e.* +182.7°, +181.5°, +181.3° for wheat, barley and oat starch, respectively).

3.8.1.7 Determination of dietary fibre

The dietary fibre was estimated using different methods which could be described as follows:

(a) Enzymatic gravimetric method (Prosky *et al.*, 1985): The sample was treated with heat-stable α amylase (Sigma Chemical Ltd.) and then digested with protease (Sigma Chemical Ltd.) and amyloglucosidase (Sigma Chemical Ltd.) in order to remove the protein and starch contents. The soluble dietary fibre was precipitated using ethanol (95%). The total residue was filtered, washed with 78% ethanol, 95% ethanol and acetone (Prolabo, Manchester, UK). After drying, the residue was weighed. One duplicate was analysed for protein and the other was incinerated at 525°C for ash. The total dietary fibre was assumed as follows :

Total dietary fibre = wt of residue - (wt of protein + ash)

(b) Enzymatic instrumental (Englyst and Hudson, 1987): The starch was gelatinised and removed enzymatically, followed by hydrolysis of any remaining polysaccharides by sulphuric acid (12 mol l^{-1}). The resulting neutral sugars were measured by complexing with dinitrosalicylate, and comparing the colour with standards at 530 nm using spectrophotometer SP 1800 (Pye Unicam, Cambridge, UK). The total dietary fibre as non-starch polysaccharides was calculated as follow:

$$\text{The NSP content } (\text{g } 100 \text{ g}^{-1}) = \frac{At \times Vt \times 100}{As \times Wt}$$

Where, At = absorbance of the test solution, Vt = total volume of test solution, As = absorbance corresponding to 1 mg sugar ml^{-1} taken from the line of best fit for the standard and Wt = weight (mg) of sample.

3.8.1.8 Determination of free sugars

The free sugars were determined according to the method of Englyst and Hudson (1987). The absorbance of the treated sample was read against the blank at 540 nm using spectrophotometer (see section 3.8.1.7).

3.8.1.9 Determination of β-Glucan

The β-Glucan of the cereals was estimated according the method described by McCleary and Glennie-Holmes (1985) (see also McCleary and Mugford (1992). The absorbance was measured using a spectrophotometer (Spectronic 20 D, Milton Roy Company, USA).

3.8.1.10 Determination of phytic acid

The method described by Latta and Eskin (1980) was used to determine the phytic acid content of the cereals. The phytate content of the sample was extracted in HCl (2.4%) and the filtrate from the extracted sample was treated with Wade's reagent (*i.e.* 0.03% ferric chloride ($Fe\ Cl_3.\ 6H_2\ O$) and 0.3% sulphosalicylic acid in water). The intensity of the colour was quantified by comparison with standards at 500 nm using a spectrophotometer (see section 3.8.1.7).

3.8.1.11 Determination of mineral contents

The mineral contents (Ca, P, Mg, Zn, Fe, Cu, Mn, K and Na) of the cereals were measured using the nitric-perchloric acid digestion procedure according to the method described by the Ministry of Agriculture, Fisheries and Food (MAFF) (1986) followed by induction coupled plasma (ICP) emission spectrometry (Thermo Electron Ltd., Birchwood, Warrington, UK). The analyses were performed with the flow rate of 15 l min^{-1}, 0.5 l min^{-1} and 0.8 ml min^{-1} for main argon, nebulizer argon and sample, respectively. The mineral eluates were monitored at different wavelengths: 317.9 nm - Ca, 214.9 nm - P, 285.2 nm - Mg, 766.5 nm - K, 589.6 nm - Na, 213.9 nm - Zn, 238.2 nm - Fe, 324.8 nm - Cu and 257.6 nm - Mn. The analysis were carried out in duplicate on each sample. The percentage of phosphate associated with phytic acid was calculated by converting the phosphorus content to phosphate (*i.e.* P x 3.065), then calculating the phosphate bound in the phytic acid (hexaphosphate inositol) by multiplying the phytic acid content by 0.888.

3.8.2 Microbiological analysis

3.8.2.1 Preparation of sample

The preparation of sample and dilutions for microbiological analysis was carried out according to the method described by IDF (1992). The cereal (10 g) was homogenised in

90 ml sterile sodium citrate solution (2%) to prepare the 1st dilution using a rotatory blender (Waring Products Division, New Hartford, Conn., USA) with a sterile stainless steel bowl fitted with a lid, or using a Colworth Stomacher 400 model BA 6021 (A.J. Seward Medical, London, UK). Further decimal dilutions (*e.g.* 1 ml) were prepared by using ¼ strength sterile Ringer's solution (*i.e.* 9 ml).

3.8.2.2 Microbilogical analysis

The total colony, coliforms and yeasts and moulds counts were determined according to the methods described in sections 3.4.8, 3.4.9 and 3.4.10, respectively.

3.8.2.3 Aerobic spore-formers

Aerobic spore-formers were counted according to the method described by Harrigan McCance (1976). The inoculum was cultured on Starch Milk Agar (SMA) [*i.e.* Nutrient agar CM 3 (Oxiod Ltd.), soluble starch 0.1% 10271 3R (BDH Chemicals Ltd.) and skimmed milk powder 0.1% L 31 (Oxoid Ltd.)] and incubated at 55°C for 48 h or at 30°C for 72 h in order to enumerate the thermophiles and mesophiles spores, respectively.

3.9 Analysis of Kishk

3.9.1 Chemical analysis

3.9.1.1 Compositional quality

Fat, protein, moisture, ash, total carbohydrates, starch, dietary fibre, free sugars, β-glucan and phytic acid contents were analysed according to the methods described in sections 3.8.1.1 to 3.8.1.10, respectively. As the Kishk was produced from cereals (1 part) and yoghurt or milk (4 parts), the protein content was calculated as follow:

Protein% = [(4/5 x 6.38) + (1/5 x 5.70 and/or 5.83)] x Nitrogen%

In effect this means that the multiplication factor becomes 6.244 for the product made from wheat and 6.27 for products made with oats and barley.

3.9.1.2 Determination of salt

The percentage of salt was determined according to the method described by BSI (1976) which is based on the principle of the reaction between the sodium chloride and silver nitrate in hot acid to form silver chloride. The difference between the titration of the excess silver nitrate with potassium thiocyanate and blank was used to calculate the salt percentage in the Kishk sample (*e.g.* 1 ml of 0.05 N potassium thiocyanate ~ 0.00292 g salt).

3.9.1.3 Determination of mineral contents

The mineral contents of Kishk was analysed according to the method described in section 3.8.1.11.

3.9.1.4 Determination of fatty acids

The fatty acids content in Kishk was determined according to the standard method BSI (1992) as described by Barrantes (1993) using gas liquid chromatography (GLC). The chromatograph Model 93 consisted of a flame ionisation detector S 100183 (Ai Scientific Cambridge Ltd., Cambridge, UK) and an integrator Spectra-Physics Model SP 4290 (San Jose, California, USA). The column was 2 m long and 2 mm internal diameter and was packed with cyansilicone derivative (SP 2330) on 100-120 mesh chromasorb (W/AW). The temperature was maintained at 50°C for 2 min, then increased at a rate of 20°C min^{-1} up to 200°C and held for 10 min. The flow rate of N_2 (as a carrier) and H_2 were ~ 20 ml min^{-1}. The chromatograph was calibrated using a set of fatty acid standards prepared in heptane (Sigma-Aldrich Company Ltd., Poole, Dorset, UK). The lipids of Kishk were extracted by the method described in section 3.9.1.1. Around 50 µl of extracted lipid was measured into a stoppered test tube and dissolved in 2 ml hexane (BDH Chemicals Ltd.). Later, 0.2 ml of 2% methanolic potassium hydroxide (*i.e.* w/v KOH in methanol) was added and shaken until the solution became clear. The solution was left to stand for ~ 10 min in order to settle the glycerol fraction to the bottom of the test tube; 0.1 µl of the supernatant was injected by means of 1 µl injection. The response factors were automatically determined by the data processing system (Chromperfect; Justice Innovations Chromatography Data Systems, Mountain View, California, USA).

3.9.1.5 Determination of organic acids

Organic acids in Kishk samples were determined according to the method described in section 3.7.

3.9.2 Microbiological analysis

The total colony, coliforms, yeasts and moulds, aerobic spore-formers and starter culture counts were determined according to the methods described in sections 3.4.8, 3.4.9, 3.4.10, 3.8.2.3 and 3.6, respectively.

3.9.3 Organoleptic assessment

Sensory profiling was carried out using a protocol successfully applied to a diverse range of commercial samples (Muir *et al.* 1995). During the preliminary stage of that study, the panel of assessors and sensory scientists agreed on a list of descriptors by which to characterise odour, flavour, after-taste and mouth feel. The panel, after acclimatization to the sensory properties of commercial Kishk, used this vocabulary to profile a complete set of samples. The attribute ratings were analysed and redundant or poorly understood terms were deleted from, and additional descriptors inserted into, the experimental vocabulary. The final vocabulary, derived for commercial products (Muir *et al.* 1995) was applied without modification, to the laboratory-made Kishk in the present study. The experimental vocabulary used to construct the sensory profiles comprised 7 attributes to describe aroma (*overall intensity, creamy/milky, acid/vinegary/sharp, fruity/sweet, cooked, cereal, cardboard*), 10 flavour attributes (*overall intensity, creamy/milky, acid/vinegary/sharp, fruity/sweet, cooked, cereal, cardboard, apple, bitter, salty*), 5 descriptors of after-taste (*overall intensity, persistence, acid/vinegary/sharp, cereal, cardboard*) and 5 terms used to describe mouth feel (*viscosity, grainy/floury/chalky texture, sticky/gluey texture, slimy texture, mouth-coating*).

The products were rated by an external panel of 15 female (non-smokers, aged 39-55 years) assessors, highly-experienced and trained in profiling a wide range of foods. Panel performance was assessed by the principles described by Hunter *et al.* (1995). Samples were treated in an identical manner. Each dried powder was reconstituted with 4 parts of cold tap water and brought to boiling point with continuous stirring. After simmering for 5 min with occasional stirring, the product was immediately served hot in ceramic cereal bowls. Assessment of the sample was carried out in isolated air-conditioned booths with controlled lighting. The order of presentation was balanced according to Muir and Hunter (1991/2). Before profiling the sample, assessors were instructed to cleanse their palate with a plain water biscuit and some cold water. Two samples were presented in each session and several sessions were carried out on each day. Rating of attributes was carried out on an undifferentiated scale with anchor points (absent, extremely strong) and was facilitated by an interactive, computer assisted data collection system (Williams *et al.*, 1996). Samples were profiled twice.

3.10 Analysis of yoghurt/Burghol or wheat flour mixture during the secondary fermentation

3.10.1 *Alpha*-amylase activity/content

The α-amylase content was determined according to the method described by Anon. (1997a). The samples were pre-equilibrated and extracted in maleate buffer (pH 6.0) with continuous stirring for 5 min at 60°C. An Amylazyme test tablet (Megazyme International Ireland Ltd., Co. Wicklow, Ireland) was added, and the mixture stirred for another 5 min at 60°C. The reaction was terminated using Trizma base (6 ml, 2g ml^{-1}, pH ~ 9), and the slurry was filtered using Whatman GF/A glass fibre filter paper. The absorbance of the filtrate was measured at 590 nm against the reaction blank using a spectrophotometer (see section 3.8.1.7)

3.10.2 Starch content

Starch content was determined by an enzymatic according to the method described by Anon. (1997b) as follows: *Firstly*, the starch was partially hydrolysed and solubilised using α-amylase. *Secondly*, the starch dextrins were then hydrolysed to glucose by using amyloglucosidase. The resulting glucose was measured colorometrically after complexing the glucose with a special reagent [*i.e.* glucose oxidase/peroxidase (GOPOD)]. The absorbance was measured and compared with standards at 510 nm using a spectrophotometer (see section 3.8.1.7).

3.10.3 Soluble protein

Non-protein nitrogen (NPN) or soluble protein was determined according to the method of IDF (1993b). The protein content of the sample was precipitated by the addition of trichloroacetic acid (TCA) solution (15 g 100 ml^{-1}) and separated by filtration (Whatman filter paper No. 1). The filtrate, which contain the soluble protein, was analysed as described in section 3.4.2.

3.10.4 Microbiological analysis

The total colony, coliforms, yeasts and moulds counts and starter culture counts were determined according to the methods described in sections 3.4.8, 3.4.9, 3.4.10 and 3.6, respectively.

3.10.5 Microscopic analysis

A Laser Scanning Confocal Microscope (LSCM) MRC-1000 (BIO-RAD Microscience Ltd., Hemel Hemstead, Herts, UK) was used to study the microstructure of Kishk during the secondary fermentation period (*i.e.* when the yoghurt was mixed with the cereal for a duration of 6 days at ~ 20°C). The samples were chemically fixed in 2.5% gluteraldehyde solution (TAAB Laboratories Equipment Ltd., Aldermaston, Berks. England) as reported by Lewis (1986), Tamime *et al.* (1991) and Kalab (1995), washed with distilled water, dehydrated in graded ethanol (70, 80, 90, 100%) and embedded in LR White acrylic resin (The London Resin Co. Ltd., UK). The embedded samples were sectioned using an UB Ultratome, type 8801 A (LKB-Producter AB, Sweden) and stained with Acridine Orange (1 g 1000 g^{-1}) (Sigma - Aldrich Company Ltd., Dorset, England). The images were recorded and stored on hard disc of the computing system connected to the microscope.

3.11 Statistical Analysis

3.11.1 Chemical composition

The data for chemical composition was analysed by univariate (analysis of Variance) and multivariate [Principal Component Analysis (PCA)] using the Genstat 5 Release 3.1 computer programme (copyright 1990, Lawes Agricultural Trust, Rothamsted Experimental Station, UK).

3.11.2 Sensory Quality

Sample effects were estimated by Analysis of Variance (ANOVA) using the General Linear Model in Minitab suite of statistical software (Release 10; Minitab Ltd., Coventry, UK). A statistical model was fitted with effects for sample, assessor, order of tasting and replicates. Of the total 27 attributes used for profiling, sample effects were significant (F test; $p < 0.05$) in 14 cases. A table of these significant effects by attribute rating was simplified by two further statistical treatments. First, Principal Component Analysis (PCA) was carried out on covariance matrices (Unscrambler v.5.03, Camo A/S, Trondheim, Norway). The PCA model was validated using cross-validation, and it identified the main attributes contributing to the variation between samples. For example, PCA is used to reduce the 14-dimensional matrix representing the sensory character of the Kishk to 4 dimensions (Principal Components), each of which is a linear combination of the original 14 attributes. The relative positions of samples in sensory space can be illustrated by constructing plots of the scores for each sample on two PCs.

In an additional separate approach, ratings for individual samples for selected attributes were coded according to five categories (*i.e.* commercial, oat, barley, wheat and porridge oats) and the effect of class on each attribute was assessed by one way ANOVA.

CHAPETER FOUR:

PRODUCTION OF KISHK USING DIFFERENT TYPES OF PARBOILED CRACKED CEREALS (BURGHOLS)

CHAPTER FOUR: PRODUCTION OF KISHK USING DIFFERENT TYPES OF PARBOILED CRACKED CEREALS (BURGHOLS)

4.1 Preliminary studies

4.1.1 Quality of the skimmed milk powder (SMP)

Traditionally, fermented milks for the production of Kishk are prepared from milks of different chemical composition, and wide variations in the composition of the product were reported by Tamime and O'Connor (1995). In the present study, in order to minimise the inherent seasonal variation in the chemical composition of milk, SMP was used as a raw material for recombination. The quality of SMP is directly related to the chemical, physical and microbiological specifications, and has great influence on the final product. The compositional and microbiological qualities of SMP were analysed, and the results are shown in Table 4.1 in comparison with the specifications recommended by Sjollema (1988). The results confirmed that the quality of SMP was within the accepted values. Thus, the insolubility index of SMP was <0.1 ml and it was free from scorched particles (Grade A). The heat number (*i.e.* the amount of nitrogen from casein + denatured whey protein, expressed as percentage of nitrogen) was 80 which classified the powder as 'medium heat' and suitable for yoghurt-making (Wilcek, 1990). The titrable acidity (0.14% lactic acid) was within the normal range, and the antibiotic test was negative, which gave the satisfactory assurance that inhibitory substances are unlikely to affect the starter culture. Microbiological specifications are within the recommended values (see Table 4.1), and it is safe to conclude that the SMP was hygienically produced and could be used for the production of yoghurt. SMPs with similar specifications were used in different studies in the Food Standards and Product Technology Department by Barrantes (1993) and La Torre (1997).

Table 4.1 Compositional and microbiological qualities of SMP.

Test	SMP values	
	A	B[a]
Moisture[b]	3.38	max. 4.0
Protein[b]	36.42	—[c]
Fat[b]	0.57	max. 1.0
Lactose[b]	51.52	—
Ash[b]	8.1	—
Titrable acidity (%)	0.14	max 0.15
Scorched particles	grade A	min grade B
Insolubility index (ml)	< 0.1	max 0.5
Heat number%	80	—
Antibiotics	-ve	—
Total colony count[d]	8.7×10^3	max. 5.0×10^4
Coliforms[d]	<10	max. 10
Yeasts and moulds[d]	<10	max. 100
Thermoduric bacteria (55° C)[d]	4.4×10^2	max. 1.0×10^4

[a] Data recommended by Sjollema (1988).

[b] Percentage (g 100 g^{-1}).

[c] Not reported.

[d] Colony forming unit (cfu g^{-1}).

4.1.2 Quality of anhydrous milkfat (AMF)

AMF was used in the recombination process for the production of low-fat yoghurt for Kishk-making. The quality of the AMF was analysed and compared with the specifications recommended by Sjolemma (1988). The results are shown in Table 4.2 and they are in agreement with such recommendations including the International Dairy Federation standard (IDF, 1977); similar specifications were reported by Tamime and Kirkegaard (1991). The microbiological quality of AMF is also shown in Table 4.2, and the results indicate that it was suitable for recombination. No lipolytic bacteria were present in the AMF at 10^{-1} dilution which demonstrates that the product was likely to be free from soapy-flavour. AMF with similar quality was used for the production of yoghurt by Barrantes (1993) and La Torre (1997).

4.1.3 Enumeration of starter culture

The starter culture MY 087 (Rhône-Poulenc Texel (UK) Ltd., Cheshire, UK) was used for the acidification of milk for the manufacturing of yoghurt, which was later used for the production of Kishk. As mentioned in section 3.1.3, the freeze-dried culture was suitable for DVI application and was stored at -40°C in a freezer until required. *Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus* were enumerated on plating out as 1.3×10^{11} cfu g^{-1} and 2.2×10^{8} cfu g^{-1}, respectively.

4.1.4 Production of Kishk/laboratory-scale method

To produce Kishk on a laboratory-scale, preliminary experiments were carried out in order to standardise the manufacturing stages which included: (a) the use of different ratios of yoghurt and Burghol in order to obtain a product (*i.e.* gross composition) similar to Lebanese Kishk (see Table 4.3), and (b) standardise the drying stage.

Three batches of Kishks (*i.e.* Burghol to yoghurt ratios 1:2, 1:3 and 1:4, respectively) were produced as shown in Figure 3.6, and to each batch, salt was added at a rate of 1.5 g 100 g^{-1}. After completion of the secondary fermentation for six days, each yoghurt/cereal

Table 4.2 Compositional and microbiological qualities of AMF.

Test	AMF values	
	A	**B**[a]
Moisture[b]	0.13	max. 0.1
Fat[b]	99.87	min. 99.9
Peroxide value[c]	0.16	max. 0.2
Total colony count[d]	30	max. 100
Coliforms[d]	<10	max. 10
Yeasts and moulds[d]	<10	max. 10
Thermoduric bacteria (55° C)[d]	<10	—[e]
Lipolytic bacteria[d]	<10	—

[a] Data recommended by Sjollema (1988).

[b] Percentage (g 100 g^{-1}).

[c] milli-equivalents (meq) of oxygen kg^{-1} of fat.

[d] Colony forming unit (cfu g^{-1}).

[e] Not reported.

Table 4.3 Chemical composition (g 100 g^{-1})[a] of Kishk using different ratios of yoghurt and Burghol.

Component[b]	Burghol to yoghurt ratios			Lebanese commercial Kishk[c]	
	1:2	**1:3**	**1:4**	**Range**	**Average**
Moisture	4.59	4.67	4.79	6.75 - 10.77	8.37
Protein	18.40	19.50	19.98	14.72 - 21.44	17.75
fat	9.48	8.46	6.94	2.43 - 11.52	6.39
Carbohydrate	65.25	64.19	64.04	61.02 - 76.74	68.83
Ash	6.87	7.85	9.04	4.06 - 9.30	7.03
Salt	3.53	3.51	3.42	0.95 - 4.48	2.84
Acidity (pH)	4.42	4.27	4.24	3.58 - 4.12	3.77

a Data was calculated on dry matter basis (DMB).

b Results are average of two determinations performed on each sample.

c After Tamime (unpublished data) (n = 25).

mixture was dried in an oven (Galenkamp Express, Loughborough, Leicestershire, UK) because: *firstly*, the climatic conditions in Scotland can not allow the mixture to be dried in the sun, *secondly*, to reduce the length of drying period by applying a constant temperature, and *thirdly*, to minimise the risk of contamination. Even though a constant temperature (~ 50°C) was maintained during these trials, the drying period was ~ 14 h which could still be considered long. This might have been due to the capacity of an oven which was small to dry the large quantity of the yoghurt/cereal mixture in each batch. The loss of vapour generated inside the oven compared with moisture content of yoghurt/cereal mixture was not sufficient to reduce the water content in a shorter period of time, and at the same time, condensation was evident inside the oven. Keeping the length of drying time constant, the ratio of kilograms of water per kilogram air should be in equilibrium with the product to be dried (Loncin and Merson, 1979). To scale-up production, it was decided to use the baking oven (section 3.2.10) for drying the yoghurt/cereal mixture, and the duration of drying was 9 h.

4.1.5 Quality of Kishk made with different ratios of yoghurt and Burghol

The average composition of the Kishk using different ratios of Burghol to yoghurt is shown in Table 4.3, and the results were compared with commercial samples of Lebanese Kishk. In view of variation in moisture content of the Kishk, the data was computed on a dry matter basis (DMB) for comparison purposes (Tamime and O'Connor, 1995). It is evident that, by increasing the ratio of yoghurt to the Burghol, the protein and ash contents were increased, whilst the fat and carbohydrate contents decreased marginally. The composition of Kishk at all the ratios used were within the range of Lebanese commercial samples of Kishk. The Kishk made with the Burghol/yoghurt mixture at a ratio of 1:4 has a composition similar to the average values of Lebanese Kishk, except that the concentration of salt was slightly higher. However, clear differences were recorded in the chemical, nutritional and sensory qualities of the Kishk made from wheat Burghol and yoghurt made from either bovine or caprine milk (Muir *et al.*, 1995).

Based on such results it was decided in the present study to produce Kishk using a cereal to yoghurt ratio at 1:4, and to reduce the proportion of salt from 1.5 to 1.0 g 100 g^{-1}.

Once the product had been successfully produced, the nutritional and organoleptic qualities of Kishk merited further investigation. In Scotland, oats and barley are widely produced, have different nutritional properties when compared with wheat and are accepted by the consumers in a variety of dishes. Thus, Kishk made with these cereals could be more acceptable to the Scottish consumers and possibly more nutritious. It could be argued also that the quality of the product could be improved by using Burghol made from oats and barley. No data is available on the production of Kishk from different cereal Burghols.

4.2 Production of Burghol from different varieties of oats and barley

Cereal component(s) and/or Burghol play an important part in Kishk-making. However, little is known about the production of Burghol from wheat or other cereals. Therefore, it was decided to produce Burghols as shown in Figure 3.3 from different varieties each of oats (Adamo, Dula, Matra, Valiant) and barley (Camargue, Maghee, Marinka, Pastoral), and use them later for Kishk-making. A cracked cereal similar to that of wheat Burghol was produced in the Lebanon under the supervision of A. Y. Tamime. No difficulties were experienced in producing the cracked products until the husk removal. The husk of both barley and oats proved heavier than the bran of the wheat, and the oats husk or hull was particularly difficult to separate. The traditional winnowing method was tried in the Lebanon and was unsuccessful, and the locally made winnowing machines were too large to handle the small quantity (~ 15 kg) of each variety of oats and barley. Closer inspection of whole oats kernel prior to cracking would have indicated that this was likely. Looking forward to conventional oatmeal production, the whole oat is roasted first to allow the groat to shrink away from the closely adherent husk and facilitate the hulling process. Even in this study, care was given to grading the grain size before hulling as separation was recognised as a problem. The cracking procedure would swell and gelatinise starch granules thus binding the groat more closely to the hull. Possibly the separated groat itself could be subjected to the cracking procedure, but it is more likely that this process would produce gruel. Another oats product widely used in Scotland is rolled oats which is produced after partial cooking of groats by steam at atmospheric pressure just prior to rolling (Fox and Cameron, 1995). This limited access to heat and moisture softens the groats and allows flaking with minimum breakage or flour formation. A possible alternative would be the use of hull-less oats. The structure of barley allowed conventional cracking procedures to be adopted and, although difficult to separate using traditional Burghol winnowing equipment, could be separated.

4.2.1 Effect of processing on the compositional quality

The effect of processing (parboiling) on the gross compositional quality of the different cereals was evaluated. The results shown in Table 4.4 indicate that, in all the parboiled 'cracked' products, the average concentration of fat, protein and ash were reduced as a result of processing. The mean fat content [g 100 g^{-1} (DMB)] in the cracked barley dropped from 3.5 to 3.1, protein 12.8 to 12.2 and ash 2.4 to 1.7, while the mean variation [g 100 g^{-1} (DMB)] between the original grain and cracked product of oats were from 8.1 to 7.8, 14.1 to 13.9 and 2.0 to 1.9 for fat, protein and ash, respectively. In case of parboiled cracked wheat, the fat content [g 100 g^{-1} (DMB)] decreased from 3.6 to 2.9, protein 16.8 to 14.8, and ash 1.9 to 1.7.

Analysis of variance shows the significant differences between the cereals in fat and protein contents ($P<0.001$), but not for ash. In addition, significant differences were found between the original grain and the cracked product for fat and protein ($P<0.05$), and for ash ($P<0.001$). The only factors with significant cereal x treatment interaction were ash ($P<0.001$), and protein ($P<0.05$).

The results of processing effect on carbohydrate fractions of different cereal varieties are also shown in Table 4.4, and revealed that there was an apparent increase in barley starch content of the cracked product of 6.37 g 100 g^{-1}. The average free sugar content was initially 0.92 g 100 g^{-1}, but the hot water steeping process reduced the free sugar of the cracked cereals to an average of 0.30 g 100 g^{-1}. Similarly, the fibre content of the barley was reduced from an average of 23.47 to 18.41 g 100 g^{-1}. The barley analysed as 'original' has had its husk removed by hand so that this should not be the source of the reduction. It is more likely that some of the non-digestible starch (estimated as 'fibre') in the original grain was rendered digestible by the cracking.

Table 4.4 Effect of processing on the compositional quality (g 100 g^{-1})[a] of different cereals.

Grain/ ANOVA[b]	Variety	Fat		Protein		Ash		Starch		Free sugar		Fibre		Phytic acid		β-glucan	
		O[c]	P[d]	O	P	O	P	O	P	O	P	O	P	O	P	O	P
Barley																	
	Camargue	3.47	3.22	12.51	10.90	2.51	1.69	61.38	70.34	0.64	0.24	23.73	15.29	1.18 (90)[e]	1.16 (82)	3.02	3.30
	Marinka	3.58	3.31	13.26	13.06	2.13	1.64	61.25	66.90	1.31	0.26	23.35	18.17	1.16 (86)	1.22 (93)	3.54	4.06
	Pastoral	3.56	2.67	12.60	12.76	2.43	1.79	61.99	66.50	0.80	0.40	23.32	21.76	1.22 (86)	1.27 (97)	2.90	3.18
Oats																	
	Adamo	10.45	9.31	14.28	13.77	2.00	1.95	63.11	65.62	0.50	0.26	13.38	10.67	1.27 (75)	1.38 (84)	3.83	3.91
	Dula	7.32	7.52	14.22	14.21	2.14	2.01	65.29	66.22	0.82	0.14	14.54	10.77	1.45 (89)	1.50 (90)	3.32	3.78
	Matra	7.31	7.12	13.87	14.13	1.93	1.96	67.70	66.17	0.94	0.14	11.30	12.54	1.41 (69)	1.36 (84)	3.11	3.56
	Valiant	7.46	7.10	13.82	13.53	1.97	1.85	65.90	67.69	0.94	0.24	11.27	10.77	1.25 (77)	1.34 (84)	3.69	3.75
Wheat																	
	Salibi	3.63	2.82 (F)[f]	16.84	14.40	1.94	1.61	64.85	66.98	0.88	0.34	12.62	13.31	1.20 (90)	1.36 (100)	0.29	0.24
			3.05 (C)		15.20		1.70		62.73		0.30		14.84		1.27 (100)		0.21
Cereal (barley/oat/wheat)		***		***								***			*		***
Treatment (O/P)		*		*		***		*		***					*		**
Cereal x treatment				*		***		*									

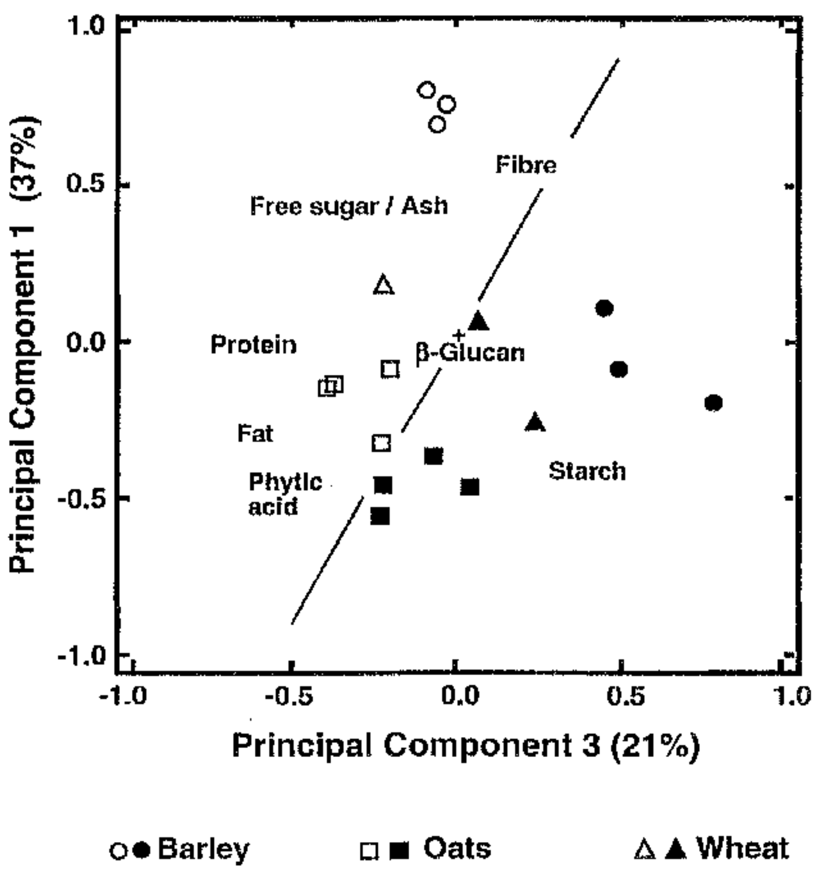
[a] All figures were calculated on dry matter basis (DMB). [b] ANOVA: analysis of variance; significance; * P<0.05, ** P<0.01, *** P<0.001.
[c] Original cereal grain. [d] Parboiled cracked grain. [e] Figures in parenthesis represent % of phosphate expressed as phytic acid.
[f] F: fine; C: coarse.
Results are average of two determinations performed on each sample.

An increase in starch content of the cracked oats (65.5 to 66.43 g 100 g^{-1}) was evident, while the free sugar content dropped from 0.8 to 0.2 g 100 g^{-1}. The 'fibre' content decreased in three of varieties of oats studied, but increased slightly in Matra (11.3 to 12.54 g 100 g^{-1}). The 'fibre' content of cracked oats was lower than wheat followed by barley. Again the average decrease was thought to be due to an increase in digestible starch. The phytic acid of the parboiled 'cracked' barley increased from 1.19 to 1.22 g 100 g^{-1}. Phytase present in the whole grain was inactivated by heating prior to the cracking procedure. The proportion of phosphorus to phytate was 87.3% and 90.6% in the original grain and cracked cereal, respectively. Such high levels of phytate phosphate would sequester most of the divalent cations, which would then be unavailable for absorption. The phytic acid of the oats in the original grain was higher (1.35 g 100 g^{-1}) than that of barley (1.19 g 100 g^{-1}). This was even greater in the cracked products as the oats phytate rose to 1.4 g 100 g^{-1}. An average of 85.5% of the phosphorus present in the cracked oats was associated with phytic acid compared to 91 and 100% for barley and wheat products, respectively.

The β-glucan content of the barley increased on cracking (3.15 to 3.51 g 100 g^{-1}), but this was probably due to the decrease of other contents. The level, as expected, was considerably higher than that of wheat (0.23 g 100 g^{-1}). Similarly, the β-glucan content of oats also increased on cracking from 3.49 to 3.75 g 100 g^{-1}.

Significant differences between the cereals were found for phytic acid ($P<0.05$), β-glucan and fibre ($P<0.001$), but not for the starch or free sugar contents. In addition, differences between the original grains and cracked products were significant for free sugar ($P<0.001$), phytic acid and starch ($P<0.05$) and β-glucan ($P<0.01$), but not for fibre. The only attribute with a significant interaction between cereal x treatment was starch ($P<0.05$).

While computing the overall relationship between the samples, Principal Component Analysis (PCA) was applied. The first PC accounted for 37%, the second PC for 25%, and the third PC for 21% variance. As a result, a two-dimensional solution accounted for 58% of the variance, and the sample scores for PCs 1 and 3, which are more readily interpretable, are shown in Figure 4.1. It is evident that the data for chemical composition



Open and closed symbols are for original grain and parboiled cracked products, respectively.

Figure 4.1 Principal Component Analysis of chemical composition of different cereals using a correlation matrix.

can be separated into original grain and parboiled cracked products. The original grain is associated with the free sugars and ash, while the parboiled product is associated with starch. Thus, calculating the correlation coefficient (Table 4.5), the starch was modestly correlated with the free sugars ($r = -0.57$, $P<0.05$), and with ash ($r = -0.68$, $P<0.01$). By projecting the observations in Figure 4.1 onto the separating line, it can be observed that the different cereals (original grain and the parboiled products) can be distinguished by their fat, fibre and phytic acid contents. Significant correlations were noted between the different attributes, and the results are shown in Table 4.5.

4.2.2 Effect of processing on mineral contents

The effect of processing on the mineral contents of the different varieties of oats, barley and wheat are shown in the Table 4.6. The calcium content of the barley varieties and wheat showed high losses after processing to the cracked products, while the other elements decreased slightly. Chloride and other water soluble anions may account for the differences. However, calcium in the cracked oats products increased from 78.9 to 88.9 mg 100 g^{-1}, but the potassium and manganese contents dropped after cracking. The iron content of all three cereal types increased in the cracked products (2.55 to 3.02 mg 100 g^{-1} in barley, 3.81 to 4.74 mg 100 g^{-1} in oats and 4.02 to 7.58 mg 100 g^{-1} in wheat). The increase in iron content in the cracked product was the second most significant change in the oats products. If this iron was available it would enhance the nutritional value.

Analysis of variance performed on the mineral elements (Table 4.6) indicated significant differences between the cereals for calcium, phosphorus, and manganese ($P<0.001$), copper ($P<0.01$), and magnesium, potassium and zinc ($P<0.05$), but not for sodium or iron. While the differences between original grain and the cracked products were significant for only copper and manganese ($P<0.001$), potassium ($P<0.01$) and zinc ($P<0.05$). The attributes with a significant interaction between cereals x treatment were calcium, copper and manganese ($P<0.05$), and potassium ($P<0.01$).

PCA was used to isolate the main differences between the cereals for mineral contents and the results are shown in Figure 4.2. The first PC accounted for 45% and the second 24%. A

Table 4.5 Matrices of significant correlations for chemical attributes.

Chemical component	Attributes				
	Starch	Free sugar	Phytic acid	β-glucan	Fibre
Ash	r[a] = -0.68 **[b]				
Fibre			r = -0.57 *		
Starch		r = -0.57 *			r = 0.55 *
Protein				r = -0.66 **	r = 0.48 *
Fat			r = -0.60 **	r = 0.54 *	r = -0.60 **

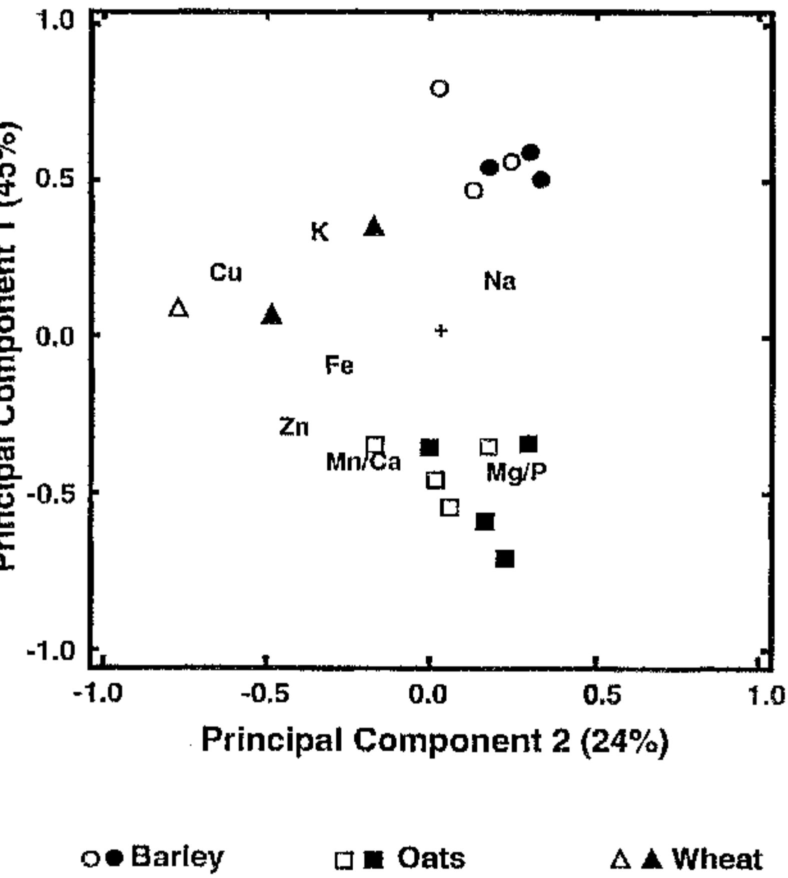
[a] Correlation.

[b] Significance: * P<0.05, ** P<0.01, *** P<0.001.

Table 4.6 Effect of processing on mineral contents (mg 100 g^{-1})[a] of different cereals.

Grain/ ANOVA[b]	Variety	Calcium O[c]	Calcium P[d]	Magnesium O	Magnesium P	Phosphorus O	Phosphorus P	Sodium O	Sodium P	Potassium O	Potassium P	Copper O	Copper P	Zinc O	Zinc P	Iron O	Iron P	Manganese O	Manganese P
Barley																			
	Camargue	48.0	43.0	126.0	125.0	381.0	408.0	7.0	6.0	682.5	430.5	0.56	0.46	1.67	1.83	2.15	2.90	1.22	1.16
	Marinka	47.5	43.5	114.5	112.0	388.0	375.0	6.5	8.0	486.0	422.5	0.34	0.32	2.87	2.50	3.17	3.31	1.76	1.10
	Pastoral	46.5	46.5	127.0	125.0	406.5	383.0	7.5	3.5	550.5	468.5	0.45	0.47	1.97	1.87	2.34	2.85	1.66	0.93
Oats																			
	Adamo	75.5	79.5	148.0	141.0	494.5	479.5	3.5	4.0	448.0	425.5	0.46	0.25	2.64	2.73	3.41	4.38	4.33	3.76
	Dula	86.5	86.0	146.0	146.0	484.5	484.0	4.0	4.0	473.0	416.5	0.33	0.26	3.26	3.43	4.17	4.96	6.11	4.83
	Matra	83.0	109.5	143.5	146.0	482.5	469.0	2.5	10.5	459.5	334.0	0.36	0.35	3.35	3.75	3.35	4.62	5.33	5.37
	Valiant	70.5	80.5	132.0	128.0	472.0	455.0	4.0	5.5	470.5	394.5	0.45	0.38	3.64	3.51	4.32	5.01	6.16	5.22
Wheat																			
	Salibi	80.5	65.0(F)[e]	121.0	113.5	390.0	358.0	4.5	3.5	575.5	453.5	0.91	0.51	3.87	3.04	4.02	3.36	4.79	2.39
			70.0(C)		122.0		378.0		4.5		476.5		0.57		3.26		11.8		2.78
Cereal (barley/oat/wheat)		***		*		***				*		**		*				***	
Treatment (O/P)										**		***		*				***	
Cereal x treatment		*								**		*						*	

[a] All figures were calculated on dry matter basis (DMB). [b] ANOVA: analysis of variance; significance; * P<0.05, ** P<0.01, *** P<0.001.
[c] Original cereal grain. [d] Parboiled cracked grain. [e] F: fine; C: coarse.
Results are average of two determinations performed on each sample.



Open and closed symbols are for original grain and parboiled cracked products, respectively.

Figure 4.2 **Principal Component Analysis of mineral contents of different cereals using a correlation matrix.**

two-dimensional solution accounted for 69% of the variance. Each cereal had clustered differently according to the mineral component in particular, oats contained high proportions of Mn, Ca, Mg and P. The copper and potassium contents were high in wheat, while the barley varieties appear deficient in minerals when compared with the other cereals. Although the different varieties of barley were clustered near the Na (Figure 4.2), the different in Na content between the cereals were found to be insignificant. Significant correlations were found for the different attributes which are summarised in Table 4.7. Mg was very strongly correlated with P ($r = 0.92$, $P < 0.001$) while with Ca and Mn the relationship was modest ($r = 0.66$, $P < 0.01$ and $r = 0.63$, $P < 0.01$, respectively). Ca was strongly correlated with Zn and Mn ($r = 0.88$, $P < 0.001$) and modestly correlated with P ($r = 0.64$, $P < 0.01$).

4.2.3 Microbiological quality

The microbiological quality of the different varieties of oats, barley and wheat Burghols used for Kishk-making were analysed, and the results are shown in Table 4.8. Total colony counts ranged between 1.1×10^3 and 2.1×10^5 cfu g^{-1}.

In all the Burghols no coliforms were evident at 10^{-1} dilution. The reason might be the drying process (50°C) applied during the preparation of Burghol for Kishk-making as mentioned in section 3.3.3.

The yeasts and moulds were recovered only from the Camargue, Marinka and Pastoral (barley) Burghols, and the counts (cfu g^{-1}) were 4.1×10^3, 2.8×10^3 and 4.6×10^3, respectively.

However, the evidence of aerobic spore-formers were expected, as these are heat resistant and can survive adverse conditions for very long periods of times. Table 4.8 shows that most of the aerobic spores were mesophilic while the thermophilic spores in all the Burghols were found in very low concentration (<10 cfu g^{-1}) with the exception of wheat and Pastoral (barley) Burghol in which the counts were 1.2×10^2 cfu g^{-1} and 1.1×10^2 cfu g^{-1}, respectively. During the production of Burghol, the cereals were steeped in boiling

Table 4.7 Matrices of significant correlations for mineral attributes.

Mineral contents	Attributes					
	Cu	**K**	**Zn**	**Mg**	**P**	**Mn**
K	r = 0.64 **					
Zn						r = 0.83 **
P		r = -0.47 *				r = 0.74 **
Mg					r = 0.92 ***	r = 0.63 **
Ca			r = 0.88 ***	r = 0.66 **	r = 0.64 **	r = 0.88 ***

[a] Correlation.

[b] Significance: * $P<0.05$, ** $P<0.01$, *** $P<0.001$.

Table 4.8 Microbiological quality (cfu g^{-1})[a] of Burghol.

Burghol	Total colony count	Coliforms	Yeasts and moulds	Aerobic spore-formers	
				Mesophiles	Thermophiles
Oats					
Adamo	1.8×10^3	<10[b]	<10	5.8×10^2	<10
Dula	1.3×10^3	<10	<10	1.2×10^2	<10
Matra	1.8×10^3	<10	<10	2.2×10^2	<10
Valiant	1.1×10^3	<10	<10	2.8×10^2	<10
Barley					
Camarguc	7.9×10^3	<10	4.1×10^3	1.1×10^2	<10
Maghee	1.3×10^4	<10	<10	1.7×10^3	<10
Marinka	2.2×10^4	<10	2.8×10^3	2.2×10^2	<10
Pastoral	5.4×10^3	<10	4.6×10^2	1.3×10^2	1.1×10^2
Wheat					
Salibi	2.1×10^5	<10	<10	2.9×10^2	1.2×10^2

[a] Results are the average of single sample plated in duplicate.

[b] No growth at 10^{-1} dilution.

water for ~ 1 h, the spore-formers could originate during the cracking stage of Burghol-making *i.e.* when parboiled grain was mixed with water (see section 3.3.3).

4.3 Production of Kishk using different cereal Burghols

A total of three trials, *i.e.* twenty seven batches of Kishks, were produced as described in Figure 3.6 using four varieties each of barley and oats, and one variety of wheat Burghol. However, in the first trial 1 g 100 g^{-1} salt was added to the yoghurt/cereal mixture which gave slightly higher salt content in the product compared to the commercial samples of Lebanese Kishk. Thus, in subsequent trials the added salt was reduced from 1 to 0.75 g 100 g^{-1}.

4.3.1 Compositional quality of Kishk

The average chemical composition of nine Kishk samples is shown in Table 4.9, while the individual trial results are illustrated in Appendix I. The protein, fat, carbohydrate and ash contents [g 100 g^{-1} (DMB)] ranged between 18.2 and 20.6 (SED = 0.3), 6.4 and 10.7 (SED = 0.42), 62.0 and 68.6 (SED = 0.68), and 6.4 and 6.8 (SED = 0.11), respectively. These results were within the range of Lebanese commercial Kishks (Table 4.3). However, the fat and carbohydrate levels were the major variable constituents among the types of cereals used for Kishk-making. Kishk made with oats had the highest fat content (mean 9.7 g 100 g^{-1}) which was due to the higher fat content of oats Burghol (Table 4.4). Salt contents were in the acceptable range found in Lebanese Kishks, although levels upto 10.8 g 100 g^{-1} have been found in Egyptian Kishks (see the review by Tamime and O'Connor, 1995). Analysis of variance showed significant differences ($P < 0.001$) in protein, fat and carbohydrate, but not for ash and salt concentration. The differences in gross chemical composition of Kishks made with different cereal Burghols may be attributed the composition of the Burghol used.

PCA was performed to calculate the relationship between the Kishk made with different cereal Burghols, and the results are illustrated in Figure 4.3. A biplot of PC on various analytical data was produced. The first two PCs accounted for 88.4% of variations (PC 1 =

Table 4.9 Chemical composition (g 100 g^{-1})[a] of Kishk made with different cereal Burghols.

Kishk samples	Moisture	Protein	Carbohydrate	Fat	Ash	Salt
Oats						
Adamo	8.12	20.52	62.02	10.71	6.75	3.66
Dula	8.02	20.59	63.22	9.46	6.71	3.70
Matra	8.22	20.61	63.43	9.28	6.68	3.67
Valiant	8.38	20.36	63.47	9.51	6.66	3.78
Barley						
Camargue	7.75	18.17	68.23	7.05	6.55	3.65
Maghee	8.84	18.16	68.64	6.62	6.59	3.73
Marinka	8.54	19.57	67.21	6.81	6.41	3.58
Pastoral	8.41	19.18	67.68	6.64	6.50	3.64
Wheat						
Salibi	8.86	20.32	66.74	6.42	6.52	3.77
SED[b]	0.83	0.30	0.68	0.42	0.11	0.08

[a] Data was calculated on dry matter basis.

[b] Standard error of difference of mean.

Results are average of three trials and of two determinations performed on each sample.

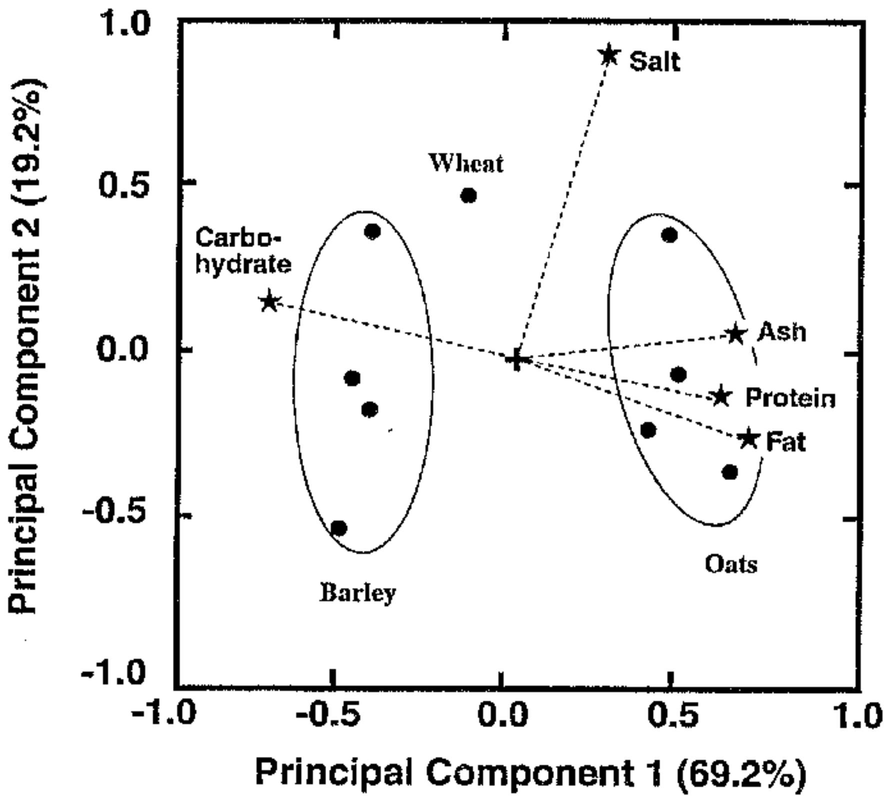


Figure 4.3 Principal Component Analysis of chemical composition of Kishk made with different Burgols using a correlation matrix.

69.2% and PC 2 = 19.2%). Each Kishk was located differently according to the type of Burghol used. Ash, protein and fat were clustered near to the oats-based Kishk, while the total carbohydrate was near to the barley-based Kishk.

4.3.2 Carbohydrate-based content

The Kishk samples contained substantial and variable amounts of carbohydrate. The average values are shown in Table 4.10, whilst Appendix II shows the individual trial results. The average starch content of oats and wheat Kishks was ~ 40 g 100 g^{-1} which was less than the barley products (*i.e.* 44 g 100 g^{-1}) (SED = 0.76), but the opposite pattern was found for free sugar content, *i.e.* the lowest values (7.6 g 100 g^{-1}) for barley Kishks and the highest (9.8 g 100 g^{-1}) for wheat Kishk followed by oats Kishk (8.9 g 100 g^{-1}) (SED = 0.62). In general, the phytic acid content (g 100 g^{-1}) of the oats, barley and wheat Kishk averaged 0.7, 0.47 and 0.48, respectively (SED = 0.06), and the level for the latter two products was half the amount found in the commercial Lebanese Kishk (Tamime, unpublished data). Since the source of phytic acid in Kishk is the Burghol, and high levels of phytate can prevent the absorption of Ca, Fe, and Zn in the body (Passmore and Eastwood, 1986), the choice of appropriate cereal variety can reduce such undesirable dietary effects. The fibre content (g 100 g^{-1}) of the oats, barley and wheat Kishks ranged between 6.2 and 7.1, 7.4 and 9.3, and 9.0, respectively (SED = 0.62). This variation in fibre content of Kishk could be attributed to: (a) the efficiency of de-husking during the Burghol-making, and (b) the different varieties of cereals used. It is of interest to note that levels of β-glucan >2 g 100 g^{-1} were found in oats (Adamo, Dula and Matra) and one barley (Marinka) Kishks. Such appreciable levels of β-glucan in some Kishk samples may suggest that these products have an enhanced dietary potential.

Significant differences were found in free sugars ($P < 0.01$), starch, fibre , β-glucan and phytic acids ($P < 0.001$). The differences in the carbohydrate-based contents between Kishks made with different cereal Burghol were calculated using PCA to the mean values (Figure 4.4). The first PC accounted for 57.5% and the second PC for 22.9% of variance. All the Kishks were clearly separated according to the variety of Burghol used. Oats- and barley-based Kishks were clustered near the phytic acid and starch, respectively while the

Table 4.10 Carbohydrate-based content ($g\ 100\ g^{-1}$)[a] of Kishk made with different cereal Burghols.

Kishk samples	Starch	Free-sugar	Fibre	β-glucan	Phytic acid
Oats					
Adamo	39.03	7.92	6.60	2.20	0.67
Dula	39.10	9.18	7.14	2.53	0.70
Matra	40.72	9.82	6.92	2.10	0.83
Valiant	42.37	8.75	6.15	1.89	0.69
Barley					
Camargue	45.15	7.43	7.35	1.73	0.49
Maghce	43.54	7.08	9.29	1.57	0.51
Marinka	43.68	7.75	8.97	2.22	0.44
Pastoral	44.62	8.12	7.88	1.81	0.45
Wheat					
Salibi	40.84	9.83	8.98	1.10	0.48
SED[b]	0.76	0.62	0.62	0.19	0.06

[a] Data was calculated on dry matter basis.

[b] Standard error of difference of mean.

Results are average of three trials and of two determinations performed on each sample.

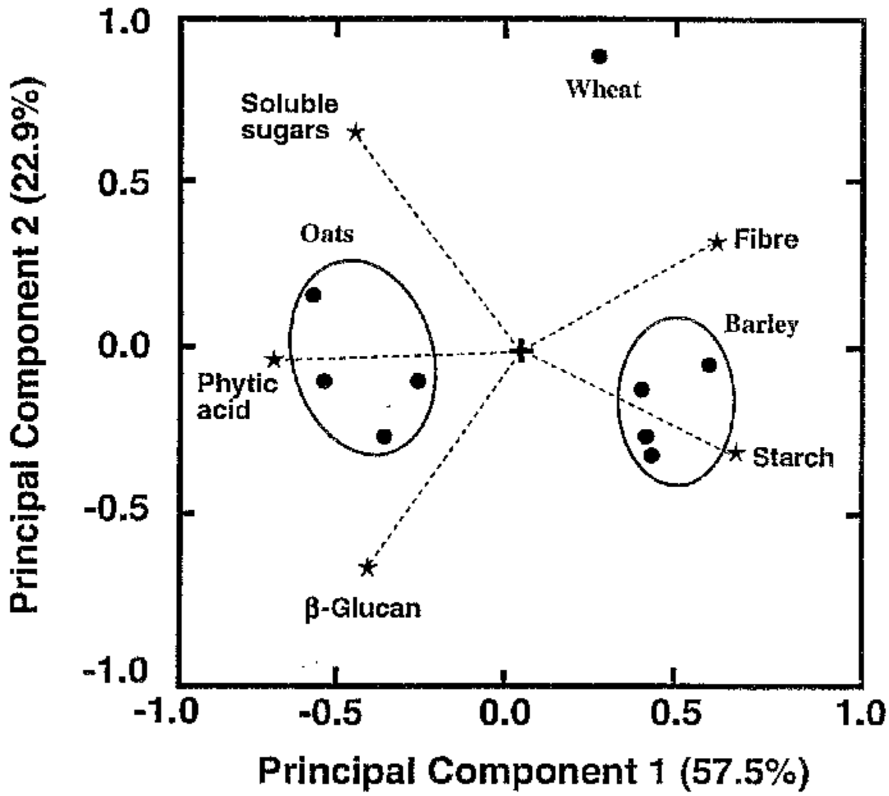


Figure 4.4 **Principal Component Analysis of carbohydrate-based content of Kishk made with different Burghols using a correlation matrix.**

wheat-based Kishk was related to the soluble sugars and fibre. It was evident that β-glucan was positively correlated with fibre while soluble sugar was negatively correlated with starch.

4.3.3 Mineral contents

Kishk made from different varieties of oats, barley and wheat were analysed for mineral contents, and slight variations in the proximate concentrations were found (Table 4.11 and Appendix III). In all the varieties of Kishks, the Na content was ~ 1359 mg 100 g^{-1} which was very high, and could be due to the addition of salt during Kishk-making. Appreciable amounts (mg 100 g^{-1}) of K (799) was found in Kishk made with wheat Burghol compared to Kishks made with oats and barley Burghols (756 and 753, respectively) (SED = 25.9). While the highest amount (mg 100 g^{-1}) of P (629) and Ca (460) were found in Kishk made with oats Burghol followed by Kishk made with wheat (549 and 439, respectively) and barley (549 and 425, respectively) Burghols (SED = 20.1 and 13.5, respectively). Such K, P and Ca contents were ~ 2-fold higher than the average content found in the commercial samples of Lebanese Kishks (Tamime, unpublished data), but lower than the same mineral contents of skimmed milk powder (Holland *et al.*, 1989). Magnesium content was the highest (~ 129 mg 100 g^{-1}) in oats-based Kishks and lowest (~ 107 mg 100 g^{-1}) in barley-based Kishks. However, in all the Kishks made with oats, barley and wheat Burghols, the magnesium content was decreased compared with the Burghols from which these were made (see Table 4.6). The reason might be that the phytic acid, which in the free form is unstable (Kent and Evers, 1994), forms a complex with minerals *e.g.* phytin, a calcium-magnesium-potassium salt of inositol hexaphosphoric acid or phytic acid. An appreciable quantity of Fe (21.6 mg 100 g^{-1}) was observed in wheat Kishk which was 2.5- to 3-fold higher than that of barley and oats Kishks, respectively (SED = 3.2). Since dairy products are deficient in Fe, Mn and Cu (Holland *et al.*, 1989), the main source of these elements might be the Burghol used (see Table 4.6).

The results of analysis of variance show significant differences in iron and copper ($P < 0.01$) and in phosphorus, calcium, magnesium, zinc and manganese ($P < 0.001$), but not for sodium or potassium. The first PC accounted for 51.0% and the second PC for 25.1%

Table 4.11 Mineral contents (mg 100 g^{-1})[a] of Kishk made with different cereal Burghols.

Kishk samples	Sodium	Potassium	Phosphorus	Calcium	Magnesium	Iron	Zinc	Manganese	Copper
Oats									
Adamo	1348	760	611	436	122	7.57	3.54	2.53	0.18
Dula	1339	761	638	462	137	10.37	3.81	3.30	0.19
Matra	1358	741	644	485	137	10.06	4.14	3.37	0.29
Valiant	1395	760	623	455	118	9.20	3.99	3.42	0.34
Barley									
Camargue	1399	754	571	439	111	8.99	2.96	0.90	0.31
Maghee	1374	740	554	437	110	7.88	3.65	0.82	0.29
Marinka	1309	730	542	419	101	6.53	3.45	1.02	0.25
Pastoral	1341	789	527	406	104	7.12	2.86	0.71	0.36
Wheat									
Salibi	1360	799	552	439	116	21.58	3.60	1.72	0.42
SED[b]	45.4	25.9	20.1	13.5	3.7	3.18	0.17	0.17	0.06

[a] Data was calculated on dry matter basis.

[b] Standard error of difference of mean.

Results are average of three trials and of two determinations performed on each sample.

of variance (Figure 4.5). A two-dimensional solution accounted for 76%. Calcium, phosphorus, magnesium and zinc contents were related to the oats-based Kishk, while wheat-based Kishk was rich with potassium, iron and copper. Not a single mineral was near to the barley-based Kishk indicating mineral deficiency compared to oats- and wheat-based Kishks.

4.3.4 Analysis of fatty acids

The fatty acid profiles of the Kishks made with different varieties of oats and barley, and wheat Burghol were analysed by the method described in section 3.9.1.4 which was based on gas liquid chromatography (GLC), and the results are summarised in Table 4.12 (see also Appendix IV). Variations in the different fatty acids contents of Kishk were observed and a box plot (Figure 4.6) shows the distribution of variables. These variables are associated with the composition of milk and cereals fat. In the present study a single source of milk was used for the preparation of yoghurt, thus the variations could arise from the cereal used. In general, cereal lipid does not contain appreciable amounts of short-chain (C4:0 - C14:0) fatty acids, but there is variation between cultivars in the distribution of long-chain fatty acids (Paul *et al.*, 1980; Pomeranz, 1991). Oats-based Kishks were substantially richer in oleic (C18:1) and linoleic (C18:2) acids than products made from barley and wheat Burghol. The total saturated, mono-unsaturated and poly-unsaturated fatty acid contents are shown in Table 4.13 and Appendix V. The oats-based products contained higher concentrations of mono-unsaturated fatty acids (34.14 g 100 g^{-1} of fat) when compared to Kishks made with barley and wheat (*i.e.* 24.9 and 25.82 g 100 g^{-1} of fat, respectively) (SED = 1.02). However, the wheat-based Kishk (g 100 g^{-1} of fat) was slightly higher in poly-unsaturated fatty acids (~ 16) than the oats-based Kishk (15.54) and barley-based Kishk (12.54) (SED = 1.42).

The fatty acid profiles of these Kishks differed, and the differences were significant for C8:0 and C18:2 ($P < 0.05$), C4:0 ($P < 0.01$) and C6:0, C10:0, C12:0, C14:0, C16:0 and C18:1 ($P < 0.001$), whilst the values for C18:0 and C18:3 were not significantly different. The PCA was applied to calculate the essential differences in the fatty acids between the various Kishks made with different cereal Burghols. The variance was encompassed by the

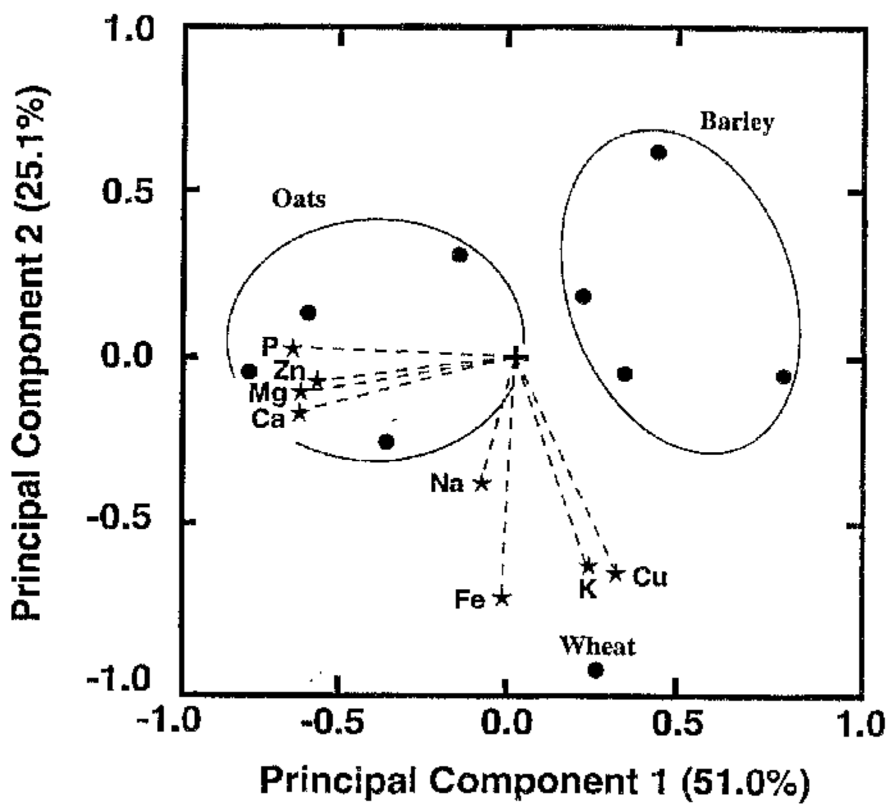


Figure 4.5 **Principal Component Analysis of mineral contents of Kishk made with different Burghols using a correlation matrix.**

Table 4.12 Fatty acids concentrations (% w/w)[a] of Kishk made with different cereal Burghols.

Kishk samples	Butyric (C4:0)	Caproic (C6:0)	Caprylic (C8:0)	Capric (C10:0)	Lauric (C12:0)	Myristic (C14:0)	Palmitic (C16:0)	Stearic (C18:0)	Oleic (C18:1)	Linoleic (C18:2)	Linolenic (C18:3)
Oats											
Adamo	1.32	1.31	0.87	1.82	2.20	8.56	22.83	6.79	37.27	15.04	1.99
Dula	1.47	1.57	0.95	2.11	2.54	9.61	26.29	6.81	33.66	12.93	2.08
Matra	1.83	1.65	0.96	2.22	2.73	10.23	25.47	7.82	32.64	12.48	1.99
Valiant	1.80	1.61	1.02	2.19	2.67	9.92	25.48	7.68	32.99	12.86	1.78
Barley											
Camargue	2.20	1.96	1.07	3.09	3.41	12.1	29.04	8.58	24.62	11.46	2.46
Maghee	2.47	1.92	1.14	2.83	3.41	12.00	28.70	9.04	25.79	10.61	2.09
Marinka	1.91	1.96	1.18	3.00	3.46	12.15	31.43	8.79	24.85	9.80	1.47
Pastoral	2.50	1.99	1.17	2.99	3.45	12.51	29.65	8.88	24.62	10.12	2.12
Wheat											
Salibi	1.80	1.71	1.03	2.90	3.16	11.05	27.69	8.84	25.82	13.10	2.89
SED[b]	0.26	0.15	0.09	0.23	0.12	0.65	0.82	0.87	1.02	1.27	0.44

[a] Data was calculated on weight of fat.

[b] Standard error of difference of mean.

Results are average of three trials and of two determinations performed on each sample.

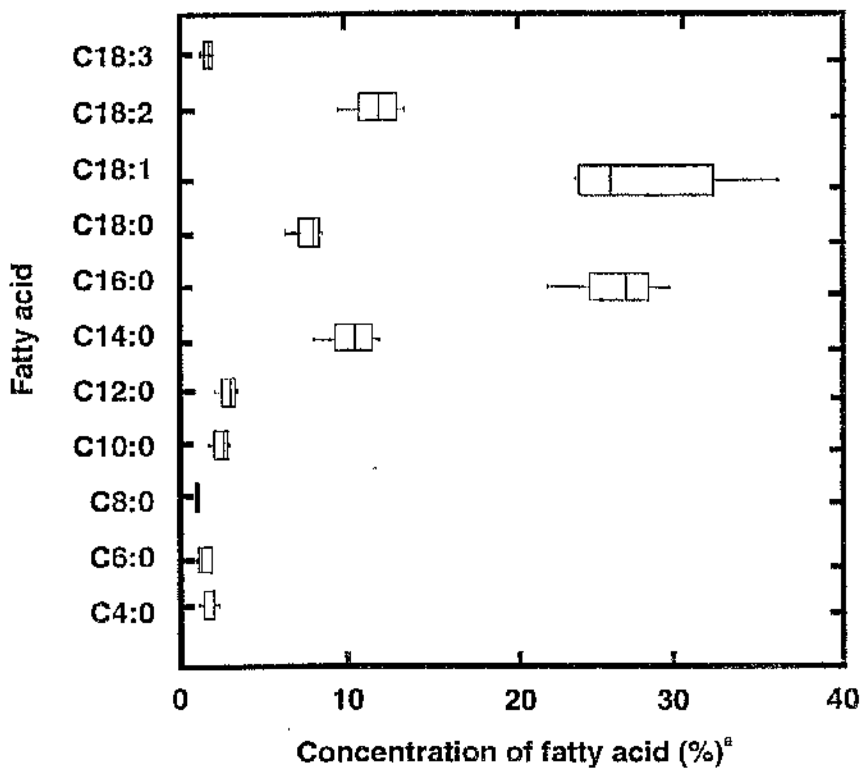


Figure 4.6 Boxplot of fatty acids concentrations of Kishk made with different Burghols.

[a] The vertical line inside the box represents the median and the vertical ends of the box represent the Ist and 3rd quartiles. Asterisks represent outliers which are further out than 1.5 x inter quartile range from the Ist and 3rd quartiles, respectively.

Table 4.13 Total fatty acids concentrations (% w/w)[a] of Kishk made with different cereal Burghols.

Kishk samples	Saturated	Mono-unsaturated	Poly-unsaturated
Oats			
Adamo	45.71	37.27	17.03
Dula	51.34	33.66	15.00
Matra	52.90	32.64	14.47
Valiant	52.37	32.99	14.64
Barley			
Camargue	61.45	24.62	13.93
Maghee	61.51	25.79	12.70
Marinka	63.88	24.85	11.28
Pastoral	63.13	24.62	12.25
Wheat			
Salibi	58.19	25.82	15.99
SED[b]	1.10	1.02	1.42

[a] Data was calculated on weight of fat.

[b] Standard error of difference of mean.

Results are average of three trials and of two determinations performed on each sample.

first two PCs as 95.2%. The first PC accounted for 83.5% and the second PC 11.7% (Figure 4.7). PC1 shows the clear separation of Kishks according to the type of Burghol used. Unsaturated fatty acids clustered near to the oats- and wheat-based Kishks, whilst all the saturated fatty acids were clustered near to the barley-based Kishks. PC2 shows the secondary differences associated with cereal variety based on poly-unsaturated fatty acids (C18:3).

4.3.5 Analysis of organic acids

The average concentrations of organic acids in the Kishks made with different varieties of oats, barley and wheat Burghol are shown in Table 4.14, and the individual trial results are reported in Appendix VI. There was no appreciable differences in the organic acid profiles of Kishks made with different types of cereals. Such observations suggest that the type of cereal used had no effect on the metabolic activity of *Lb. delbrueckii* subsp. *bulgaricus* and *Str. thermophilus*. The average concentration ($\mu g\ g^{-1}$) of lactic acid in the Kishks (19416.5) was the highest, followed by citric acid (233.2), acetic acid (56.5), pyruvic acid (47.6), hippuric (36.5), orotic (25.6) and uric/formic acid (20.3) (SED = 694.7, 35.2, 10.38, 9.19, 3.92 and 2.04, respectively). Little published data are available for organic acids in Kishk. However, comparing the results in this study with the survey reported by Tamime (unpublished data) on commercial Kishk samples (Table 4.15), the following observations/comparisons could be made: *Firstly*, the level of lactic acid in the experimental Kishk was ~ 1.7-fold lower compared with the commercial samples of Lebanese Kishk indicating that the secondary fermentation stage (*i.e.* when the yoghurt and Burghol were mixed and left at ambient temperature for one week) was poorly controlled resulting in a high level of lactic acid in the final product. *Secondly*, the acetic acid content was ~ 10-fold lower reflecting that different strains of lactic acid bacteria were used to ferment the milk. *Thirdly*, no propionic acid was detected in Kishk made with either oats, barley or wheat Burghol, but in commercial samples the content ranged between 917 and 7452 $\mu g\ g^{-1}$ suggesting the presence of propionic acid bacteria in the starter culture used. Nevertheless, the combined level of organic acids in Kishk samples was sufficiently high to ensure the microbiological safety of the product.

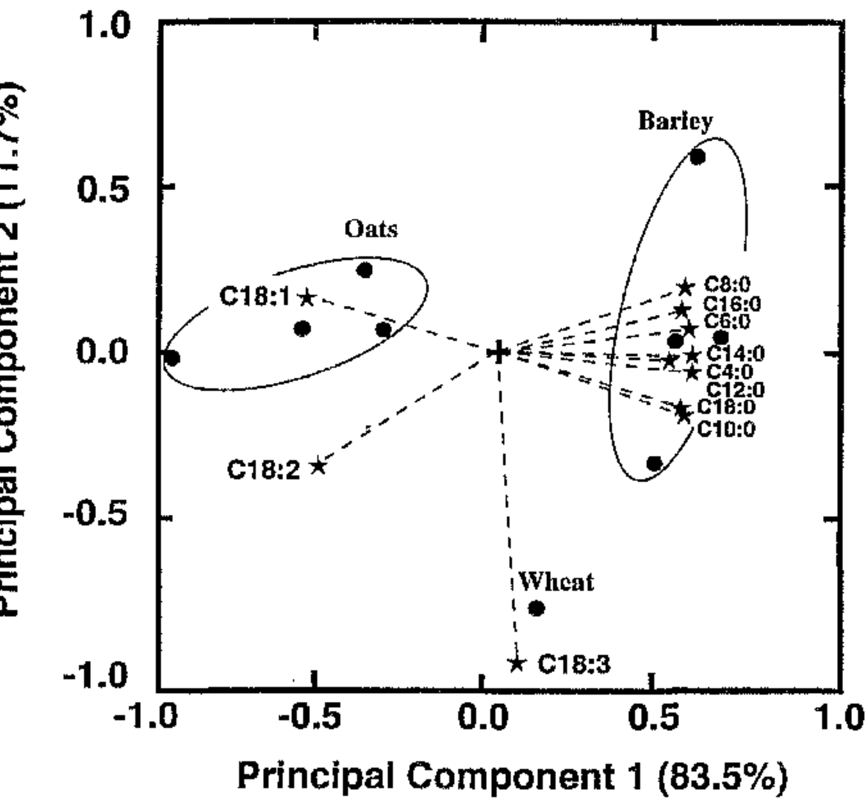


Figure 4.7 Principal Component Analysis of fatty acids of Kishk made with different Burghols using a correlation matrix.

Table 4.14 **Organic acids contents ($\mu g\ g^{-1}$) of Kishk made with different cereal Burghols.**

Kishk samples	Orotic	Citric	Pyruvic	Lactic	Uric/formic	Acetic	Hippuric
Oats							
Adamo	27.33	251.70	44.00	19792	17.00	42.33	37.33
Dula	26.00	229.00	51.00	19463	14.33	48.67	43.67
Matra	28.00	271.30	44.00	20580	16.00	42.33	38.00
Valiant	27.00	227.00	40.00	20112	13.67	62.33	38.67
Barley							
Camargue	29.00	288.30	60.00	18936	19.67	39.00	35.00
Maghce	26.67	204.00	48.00	19258	21.00	53.33	36.67
Marinka	25.67	233.70	44.00	19494	21.00	55.67	36.00
Pastoral	26.00	244.00	41.00	18319	24.00	79.33	36.00
Wheat							
Salibi	23.00	212.30	49.67	19261	24.33	63.67	34.00
SED[a]	3.19	35.23	9.19	694.7	2.04	10.38	3.92

[a] Standard error of difference of mean.

Results are average of three trials and of two determinations performed on each sample.

Table 4.15 Comparison of organic acids contents ($\mu g\ g^{-1}$) of different Kishk samples.

Organic acids	Kishk samples			
	Oats[a]	Barley[a]	Wheat[a]	Commercial[b]
Orotic	27.08	26.84	23.00	5
Citric	244.75	242.50	212.30	69
Pyruvic	44.75	48.25	49.67	38
Lactic	20011.75	19001.75	19261.00	32467
Uric/formic	15.25	21.42	24.33	24
Acetic	48.92	56.83	63.67	587
Hippuric	39.42	35.92	34.00	—
Propionic	—[c]	—	—	200-6200

[a] Experimental Kishks and results are average of three trials.

[b] Data compiled from Tamime (unpublished data).

[c] Not reported.

4.4 Microbiological quality of Kishk

The microbiological quality of the Kishk samples is illustrated in Table 4.16. The total colony counts (cfu g^{-1}) of non lactic acid bacteria were detected within the range of 7.0 x 10^3 and 1.9 x 10^5. Apparently, similar results were reported for commercial samples of Kishk in Egypt (El-Sadek and Mahmoud, 1958); higher total counts were reported by Atia and Khattab (1985), Al-Mashhadi *et al.* (1987) and Tamime (unpublished data). However, the presence of such micro-organisms in Kishk might be post-fermentation contamination and/or as a carry over from the Burghol. It is most likely that the increase in total counts has originated from the Burghol (see Table 4.8), because the milk base was subjected to high heat treatment.

Coliforms were not recovered at 10^{-1} dilution from any of the Kishk samples. Such results were similar to those found in the Burghol, while the acidic condition of the product, the presence of salt and the drying could have had a limiting effect on the growth of coliforms.

In all three trials, the yeasts and moulds counts were very low (*i.e.* <10 cfu g^{-1}) with the exception of Camargue, Marinka and Pastoral (barley-based) Kishks. The average counts (cfu g^{-1}) were 1.4 x 10^2, 1.1 x 10^4 and 3.2 x 10^2, respectively. The source could be also the Burghol used for Kishk-making (see Table 4.8).

The aerobic spore-formers in Kishk could have originated from the Burghol (see Table 4.8) and/or SMP (see Table 4.1), since these micro-organisms are heat resistant. Most of the aerobic spore-formers were mesophiles, and relatively similar counts were found in all the Kishks in the three trials. It is of interest to point out that the counts of mesophilic spore-formers in the Kishks remained the same as those of the Burghol (see Table 4.8); however, on some occasions these organisms were not recovered at 10^{-1} dilution in some products made with oats Burghol (Matra) or barley Burghol (Camargue, Marinka and Pastoral) (Table 4.16). The reason(s) could be the acidic condition originating from the yoghurt. In general, the thermophilic spore-formers counts were low (*i.e.* <10 cfu g^{-1}) because similar counts were found in the Burghol (Table 4.8). However, only very few samples contained thermophilic spores, and counts which ranged between 1.3x10^2 and 3.8x10^2 cfu g^{-1} (Table

Table 4.16 Microbiological quality (cfu g^{-1})[a] of Kishk made with different cereal Burghols.

Kishk samples	Total colony count	Coliforms	Yeasts and moulds	Aerobic spore-formers	
				Mesophiles	Thermophiles
Trial 1st					
Oats					
Adamo	2.5×10^4	<10[b]	<10	1.6×10^2	<10
Dula	4.2×10^4	<10	<10	1.4×10^2	<10
Matra	3.4×10^4	<10	<10	1.7×10^2	<10
Valiant	5.6×10^4	<10	<10	4.5×10^2	<10
Barley					
Camargue	4.4×10^4	<10	1.5×10^2	<10	<10
Maghee	1.4×10^4	<10	<10	1.5×10^2	<10
Marinka	1.2×10^5	<10	2.5×10^4	<10	<10
Pastoral	2.5×10^4	<10	4.5×10^2	<10	<10
Wheat					
Salibi	7.0×10^3	<10	<10	1.2×10^2	1.3×10^2
Trial 2nd					
Oats					
Adamo	5.4×10^4	<10	<10	1.3×10^2	<10
Dula	7.8×10^4	<10	<10	1.7×10^2	<10
Matra	4.4×10^4	<10	<10	1.2×10^2	<10
Valiant	8.0×10^4	<10	<10	4.8×10^2	<10
Barley					
Camargue	4.3×10^4	<10	1.3×10^2	<10	<10
Maghee	2.7×10^4	<10	<10	2.9×10^2	<10
Marinka	1.9×10^5	<10	2.1×10^3	<10	<10
Pastoral	2.1×10^4	<10	1.9×10^2	<10	<10
Wheat					
Salibi	7.3×10^3	<10	<10	3.3×10^2	2.0×10^2
Trial 3rd					
Oats					
Adamo	9.2×10^3	<10	<10	1.7×10^2	3.8×10^2
Dula	5.2×10^4	<10	<10	1.2×10^2	1.5×10^2
Matra	7.2×10^4	<10	<10	<10	1.3×10^2
Valiant	4.1×10^4	<10	<10	2.1×10^2	<10
Barley					
Camargue	7.8×10^4	<10	1.4×10^2	<10	1.4×10^2
Maghee	4.8×10^4	<10	<10	4.3×10^2	<10
Marinka	9.3×10^4	<10	4.9×10^3	<10	<10
Pastoral	4.3×10^4	<10	3.1×10^2	<10	<10
Wheat					
Salibi	1.4×10^4	<10	<10	2.2×10^2	2.9×10^2

[a] Results are the average of single sample plated in duplicate.

[b] No growth at 10^{-1}dilution.

4.16).

It is evident that the micro-organisms that have been detected in Kishk made with Burghols of different cereals were at too low a level to be significant (Table 4.16), and the main source of contamination is the cereal. However, such microbiological counts in Kishk suggest that the manufacturing stages were carried out under good sanitary conditions. Furthermore, the acidic nature of the product, the presence of salt and low moisture content were sufficient to control the growth of spore-formers.

4.5 Organoleptic evaluation

The sensory quality of laboratory-made Kishk with different varieties of oats, barley, and wheat Burghol were compared with two commercial samples of Lebanese Kishks (*i.e.* believed to employ wheat and bovine milk as raw materials), and a sample of porridge oats. The results suggested the following:

Firstly, a univariate analysis was used and the discriminant attributes , *i.e.* those with significant sample effects, are shown in Table 4.17. Only 14 of the original 27 attributes were useful discriminants. This reduction in diversity reflected the fact that the Kishk was manufactured under closely controlled laboratory conditions, and that a common yoghurt base was used throughout. Although this reduction in diversity was noted during acclimatisation trials, it was resolved to use the full vocabulary to ensure comparability between the present and earlier studies (Muir *et al.*, 1995). All the samples were rated for *cooked* and *cereal* aroma, whilst *creamy/milky* character was secondary importance. *Acid, salty*, and *cardboard* flavours were perceived as important flavour notes with *apple* being less important. The Kishk had an intense and persistent after-taste. As might be anticipated, the hot gruels made from Kishk were also perceived as *viscous, grainy, sticky* and *slimy* with respect to mouth feel and texture. There was no evidence of systematic differences in odour, flavour or after-taste being associated with cereals. Products based on oats and barley were more *viscous*, *sticky* and *slimy,* and less *grainy* than Kishk made from wheat. Looking forward to commercial samples, sample (B) (see Table 4.17) was notable for its high ratings for *creamy*, *cooked* and *cereal* aroma. This sample was also given a

Table 4.17 Attribute rating for significant (F test; $p < 0.05$) sample effects[a] of Kishk made with different cereal Burghols.

Samples	Aroma			Flavour					After-taste		Mouth feel and texture			
	Creamy	Cooked	Cereal	Intensity	Acid	Cardboard	Apple	Salty	Intensity	Persistence	Viscosity	Grainy	Sticky	Slimy
Oats-based Kishk														
Adamo	13.6	53.2	46.2	63.6	55.0	35.7	18.6	36.8	55.2	51.6	71.8	39.7	62.1	22.5
Dula	16.3	51.3	37.4	59.7	57.5	38.2	19.4	23.6	55.9	53.7	70.5	29.1	62.5	29.9
Matra	13.4	47.1	41.4	61.9	49.2	34.5	23.5	31.1	54.3	51.4	71.6	33.0	63.4	30.3
Valiant	16.6	49.5	41.5	65.1	55.5	36.1	19.8	30.7	55.3	52.5	70.0	29.0	62.5	29.5
Barley-based Kishk														
Camargue	11.9	49.0	40.5	57.4	46.9	28.5	21.7	28.9	47.5	46.3	68.5	33.1	53.3	26.0
Maghee	12.1	49.5	44.4	62.5	49.3	41.3	16.1	33.2	55.8	52.9	71.9	41.6	58.4	25.7
Marinka	12.1	47.2	36.9	62.5	51.1	36.1	22.0	36.0	53.4	51.4	69.2	43.5	60.0	21.2
Pastoral	13.1	45.4	41.1	61.7	53.6	37.2	19.1	30.0	51.6	49.2	73.4	41.5	60.9	17.2
Wheat-based Kishk														
Salibi	15.9	46.4	43.0	61.9	51.1	26.4	23.9	32.0	53.9	50.3	64.7	48.4	43.2	16.1
Commercial Kishk														
A	16.1	47.7	43.4	63.2	53.2	29.6	20.7	37.9	54.7	52.5	66.9	41.0	55.7	25.3
B	20.6	56.0	47.5	69.8	56.5	34.2	21.1	45.6	56.0	54.3	65.1	49.3	48.2	16.6
Porridge oats	15.3	54.8	50.8	57.9	39.6	30.3	9.7	28.1	50.0	43.4	75.9	55.6	63.8	15.7
SED[b]	2.9	3.5	4.6	3.0	5.7	5.6	4.4	6.0	3.1	3.5	2.8	4.6	4.4	4.5

[a] Sample effects for sensory attributes (scale 0 - 100).

[b] Standard error of difference of mean.

high rating for flavour *intensity*, *acid* and *salty* character, and for both the *intensity* and *persistence* of after-taste. It was interesting to note that cooked porridge oats was perceived as substantially less *acid* than Kishk and lacking in *apple* flavour. In terms of mouth feel and texture, porridge oats was different from Kishk and perceived as *viscous*, *grainy* and *sticky* with little *slimy* character.

Although univariate analyses provided a useful description of the test samples on an attribute by attribute basis, it was difficult to judge the main differences between samples or to perceive product groupings.

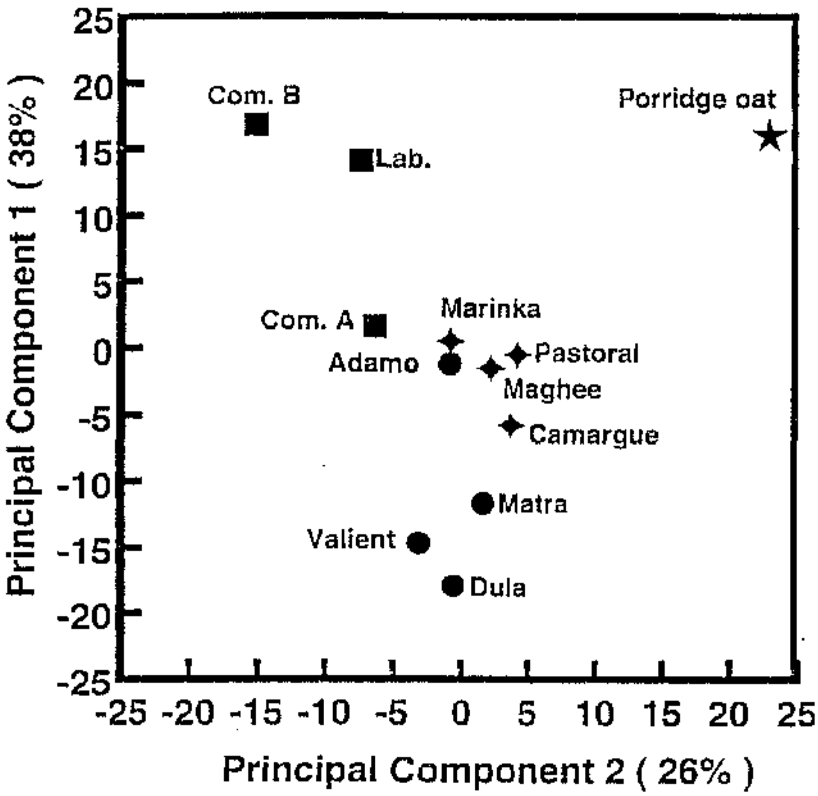
Secondly, multivariate analysis was used to achieve these objectives, and the results are shown in Table 4.18. Examination of residual variance after cross-validation suggested the six PCs, explaining 91.9% of the variance were warranted. However, 83.9% of the variance was accounted for by four PCs explaining 37.9, 25.5, 14.9 and 5.6%, respectively. Interpretation of the main dimensions in terms of original attributes was facilitated by examination of the vector loading and by consideration of the correlation of the sample scores on each PC with original attribute ratings. The first PC was associated with contrast between *grainy* texture ($r = 0.96$) and *slimy* character ($r = -0.91$). Interpretation of second PC was more complex because this dimension was related to viscosity ($r = 0.86$), *acid* flavour ($r = -0.80$) and *apple* flavour ($r = -0.76$). In addition the high vector loading ($r = 0.45$) on *sticky* texture indicated that this attribute made a secondary contribution to the second PC. The third PC was related to the *cardboard* flavour ($r = 0.71$) with additional contributions from *sticky* texture, *salty* flavour and *cooked* aroma. No single attribute was closely associated with the fourth PC, but the vector loading suggested involvement of *cooked* and *cereal* aroma, *cardboard* flavour and *slimy* texture.

Sensory space maps were constructed from the sample scores on the first and second PCs (Figure 4.8), and on third and fourth PCs (Figure 4.9). In the main dimensions (Figure 4.8), samples were mainly separated on the basis of texture and mouth feel. As found previously by Muir *et al.* (1995), Kishk was perceived quite differently from porridge oats, even in the present study when the Kishk included Burghol from oats as the cereal component. With the exception of one oats (Adamo-based Kishk), all the laboratory-made Kishk were

Table 4.18 Interpretation of sensory dimensions after Principal Component Analysis of attribute rating for significant sample effect; vector loading and correlation of PC scores with attribute ratings.

Sensory Attribute	1st PC		2nd PC		3rd PC		4th PC	
	Loading	Correlation	Loading	Correlation	Loading	Correlation	Loading	Correlation
Aroma								
Creamy	0.08	0.34	-0.14	-0.49	0.10	0.25	0.26	0.39
Cooked	0.10	0.33	0.04	0.09	*0.30*	*0.57*	*0.47*	*0.61*
Cereal	0.24	0.69	0.11	0.25	0.23	0.38	*0.45*	0.55
Flavour								
Intensity	0.06	0.22	-0.28	-0.76	0.27	0.54	0.03	-0.05
Acid	-0.15	-0.35	**-0.44**	**-0.80**	0.19	0.26	-0.19	-0.30
Cardboard	-0.18	-0.47	-0.01	-0.01	**0.48**	**0.71**	*-0.43*	*-0.43*
Apple	-0.08	-0.26	-0.32	**-0.76**	-0.27	-0.46	-0.12	-0.29
salty	0.26	0.52	-0.40	-0.63	*0.33*	*0.38*	0.12	0.03
After-taste								
Intensity	-0.04	-0.16	-0.18	-0.61	0.23	0.56	-0.03	-0.13
Persistence	-0.09	-0.31	-0.28	-0.81	0.19	0.40	-0.08	-0.24
Mouth feel								
Viscosity	-0.06	-0.22	**0.32**	**0.86**	0.20	0.39	-0.12	-0.03
Grainy	**0.69**	**0.96**	0.17	0.18	0.12	0.10	-0.27	-0.01
Sticky	-0.33	-0.60	**0.45**	**0.62**	*0.44*	*0.45*	-0.06	0.02
Slimy	**-0.44**	**-0.91**	-0.05	-0.08	0.01	0.01	*0.40*	*0.20*
Variance explained (%)	37.9		25.5		14.9		5.6	

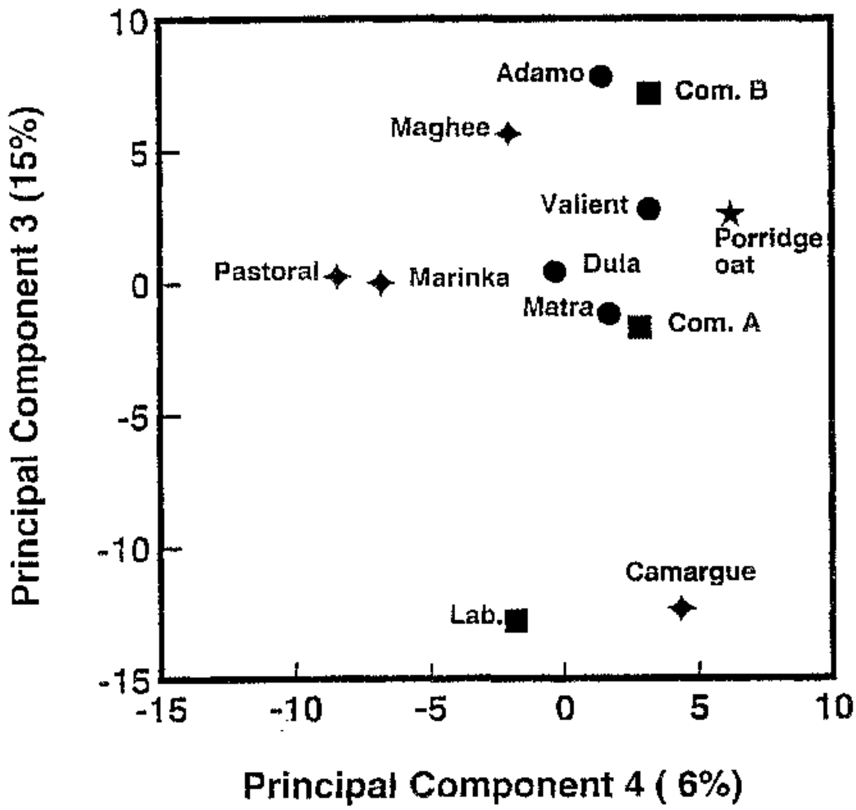
Emboldened attributes are believed to be of primary importance; italicised attributes may be of secondary importance.



● ✦ ■ : Oats-, barley- and wheat-based Kishk, respectively.

Com: commercial, Lab: laboratory-made Kishk, respectively.

Figure 4.8 First and second Principal Component biplot of sensory space maps of different samples of Kishk.



●✦■ : Oats-, barley- and wheat-based Kishk, respectively.

Com: commercial, Lab: laboratory-made Kishk, respectively.

Figure 4.9 Third and fourth Principal Component biplot of sensory space maps of different samples of Kishk.

clustered on the basis of cereal type (Figure 4.8). The two commercial Lebanese samples (*i.e.* both wheat-based) tended towards the domain of the laboratory-made wheat-based Kishk. However, it is likely that the higher fat content of the commercial Kishk samples confound interpretation of this picture. Barley-based Kishks were even more clearly separated from oats-based Kishk on the third and fourth PCs (Figure 4.9), although it is noteworthy that, in contrast to the oats-based Kishk and porridge oats, the barley-based products were highly dispersed in the sensory space. Once more, the laboratory-made wheat Kishk sample was distinctly separated from the corresponding oats- and barley-based products.

There were clear indications from the PCA that the Laboratory-made Kishks were distinguished on the basis of their cereal component. Therefore, the samples were partitioned into five groups (0, commercial; 1, oats-based; 2, barley-based; and 3, wheat-based Kishks; and 4, porridge oats).

Thirdly, the differences in attributes, found to contribute most to the major PCs (Table 4.18), were examined by ANOVA. The group means for the selected attributes are shown in Table 4.19. There was no evidence that aroma was associated with group, and the significant differences in *acid* aroma and *apple* flavour were associated with the contrast between Kishk and porridge oats. However, the differences in mouth feel and texture (*viscosity, grainy, sticky*) suggested a true link between cereal type and texture.

4.6 Conclusions

Different ratios of wheat Burghol and yoghurt were used for the manufacture of Kishk, and a ratio of 1:4 was chosen. The Burghol and yoghurt mixture after secondary fermentation was dried in an oven, but the length of drying was too long due to its small capacity. To scale-up production, a baking oven (section 3.2.10) was found to be more efficient for drying. The chemical composition of laboratory-made Kishks were within the range of commercial samples of Lebanese Kishk. The use of different types of cereals (*i.e.* barley and/or oats varieties) offers new possibilities for the production of Burghol for Kishk-making. However, some difficulties, particularly in oats, were experienced during Burghol

Table 4.19 Selected attribute ratings for grouped samples.

Group	Samples	Attribute rating for samples in group								
		Aroma			Flavour		Mouth feel and texture			
		Cooked	Cereal	Acid	Cardboard	Apple	Viscosity	Grainy	Sticky	Slimy
	Kishk									
0	Commercial	51.9	45.5	54.8	31.9	20.9	66.0	45.1	52.0	21.0
1	Oats-based	50.3	41.6	54.3	36.1	20.3	71.0	32.7	62.6	28.1
2	Barley-based	47.8	40.7	50.2	35.8	19.7	70.8	39.9	58.6	22.5
3	Wheat-based	46.4	43.0	51.5	26.4	23.9	64.7	48.8	43.2	16.1
4	Porridge oats	54.3	50.8	39.6	30.3	9.7	75.9	55.6	63.8	15.7
Significance (F test)		ns	ns	*	ns	*	**	*	***	ns

Significance; ns = not significant; * P<0.05; **, P<0.01, ***, P<0.001.

production because the husk adhered closely to the grain which was difficult to separate using conventional Burghol technology. It could be argued, however, that the modifications to the process of cracking or the use of naked or hulled barley or oats would facilitate the production of cracked products from the cereals. In all the parboiled cracked products (Burghol) made from different varieties of barley and oats and wheat, the majority of nutrients were reduced. These losses might be controlled by adjustment of the processing conditions. When barley was compared to wheat and oats using a variety of baked products, it significantly reduced serum cholesterol in four weeks (Newman *et al.*, 1989). By analogy, the cracked product could have the same beneficial effect. There was an increase in the starch, β-glucan and phytic acid contents in both of barley and oats Burghol. However, the increase in phytic acid remains under question.

Variations in the proximate composition, carbohydrate-based components, fatty acids and mineral contents in Kishk made with different cereal Burghols were observed. Kishk is a good dietary source of β-glucan, fibre, mono-unsaturated fatty acids and certain minerals especially when made from oats Burghol. The high level of Fe in wheat Kishk should not be overlooked. Principal Component Analysis was used on the correlation matrix of all the data of the 9 different samples of Kishk, and for all the analytical results PC biplots, identified groups of Kishk based on the type of cereal Burghol used.

The microbiological quality of the Kishks was very good. This could be attributed to factors such as: (a) low moisture content, (b) low pH, (c) presence of salt, and (d) presence of a wide range of organic acids. The source of some micro-organisms in Kishk (*i.e.* non lactic acid bacteria) may have been the Burghol. Also the low microbial counts in the product may suggest that : (a) the production of laboratory-scale Kishk was carried out under good sanitary conditions and hygiene standards, and (b) the microbial level may not be significant from a public health stand point.

The sensory properties of Kishk were influenced by the type of Burghol used (*i.e.* oats, barley or wheat). As expected, the perceived sensory attributes of these hot gruel products such as the aroma (*cooked* and *cereal*), flavour (*acidic* and *apple*), and mouth feel and texture attributes (*viscous, grainy* and *sticky*) differentiated the Kishk samples from the porridge oats. In addition, the sensory space maps differentiated the Kishk samples on the basis of cereal type. As a result, further exploration of the relationship between the sensory attributes of the Kishk and Burghol type is merited.

CHAPTER FIVE:

PRODUCTION OF KISHK USING DIFFERENT TYPES OF CEREALS (PORRIDGE OATS, OATS FLOUR, WHEAT BURGHOL AND WHEAT FLOUR), VARIOUS ACIDULANTS AND 'MILK'

CHAPTER FIVE: PRODUCTION OF KISHK USING DIFFERENT TYPES OF CEREALS (PORRIDGE OATS, OATS FLOUR, WHEAT BURGHOL AND WHEAT FLOUR), VARIOUS ACIDULANTS AND 'MILK'

5.1 Preliminary studies

5.1.1 Quality of SMP, AMF and enumeration of starter culture

The quality of SMP and AMF for the production of Kishk using various acidulants (D-glucono-δ-lactone (GDL) or yoghurt), 'milk' (*i.e* not fermented or chemically acidified) and starter culture for the production of yoghurt were similar to those described in sections 4.1.1, 4.1.2 and 4.1.3, respectively. Thus, the specifications are the same for this experiment.

5.1.2 Production of direct acidified milk using GDL

Milk may be coagulated in various ways, one of which is by dropping its pH to near the isoelectric point of casein. This can be achieved either by the action of bacteria producing organic acids or by chemical acidification such as direct addition of food grade acid (*e.g.* lactic, acetic, phosphoric, citric acids) or D-glucono-δ-lactone (GDL) (Rosenthal, 1991). GDL was successfully used for the manufacture of Cottage cheese (Deane and Hammond, 1960) and Cheddar cheese (Mabbitt *et al.*, 1955), and as an ingredient in milk-clotting preparations (Anon., 1970, 1971). This is a neutral compound, but is unstable in water and is hydrolysed in time to gluconic acid and gives a "slow release" of acidulant. As a consequence, the pH drops gradually and coagulation occurs at the appropriate pH (*i.e.* 4.6). However, in order to find out the right percentage of GDL to be used to gel the milk in similar manner to that of yoghurt prepared using starter culture, some preliminary trials were carried out using different percentages of GDL as follow: *firstly*, preheated milk (90°C) was divided into 20 batches, and *secondly*, GDL was added at a rate of 2, 4, 6, 8, 10, 12, 14, 16, 18 or 20 g 100 g^{-1} at 5°C. In another set of trials, similar percentages of GDL were used and mixed with milk at 45°C. Both sets were incubated at the appropriate temperatures (*i.e.* 5 or 45±1°C) (see Appendix VII). From these results, 2 g 100 g^{-1} of GDL at 45°C was found to be the right dosage for the production of a gel similar to yoghurt. Some variation in the rate of pH fall was observed at 45°C.

Another trial was carried out using GDL at a rate of 1, 2 or 3 g 100 g^{-1}, in preheated milk (90°C) incubated at 45° C (±1°C) (Table 5.1). The drop in pH was noted and once again the rate 2 g 100 g^{-1} of GDL was found to be appropriate. The pH dropped to 4.37 within 3 h and a further drop to pH 4.15 during over night cold store at 5-8°C. Once again the character of the gel was similar to that of yoghurt. The gel made with 3 g 100 g^{-1} of GDL showed excessive Syneresis after 1 h, the pH dropped to 4.33 in 1 h and to 3.8 after cold storage over night at 5-8°C; however, no improvement in gel characteristic(s) was observed. When GDL was used at a rate of 1 g 100 g^{-1} the drop in pH to 4.81 required 7 h, and the gel was very weak after storage over night at 5 - 8°C, and no further drop in pH was observed. Thus, from these limited trials it was decided to add GDL at a rate of 2 g 100 g^{-1} to preheated milk at 45°C to produce direct acidified milk suitable for Kishk-making.

5.2 Quality of cereals (Porridge oats, oats flour, wheat Burghol and wheat flour)

5.2.1 Compositional quality

The chemical composition of different cereals used in Kishk-making is shown in Table 5.2. The moisture content varied between 9.6 and 12.3 (g 100 g^{-1}); thus, the data was computed on a dry matter bases (DMB) for comparison purposes. The over all fat content of cereal averaged 5.3 g 100 g^{-1}, and the range was found to be between 2.1 and 8.3 g 100 g^{-1} (*i.e.* wheat flour (supplier B) and porridge oats (supplier A), respectively). The porridge oats and oats flour contained higher fat content when compared to Burghol and wheat flour. Similar observation was reported by Tamime *et al.* (1997a) for Burghol made from wheat,

Table 5.1 Gel formation and pH change in milk using different percentages of D-glucono-δ-lactone at 45°C.

GDL ($g\ 100\ g^{-1}$)	Incubation temperature (±1°C)	pH			
		Start	End	Time (h)	After over night cold storage at 5-8° C
1	45	6.11	4.81	7	4.83
2	45	5.89	4.37	3	4.15
3	45	5.70	4.33	1	3.80

Table 5.2 Chemical composition (g 100 g^{-1})[a] of different cereals.

Sample	Moisture	Fat	Protein	Ash	Carbohydrates					Phytic acid
					Total[b]	Starch	Free-sugar	Fibre	β-Glucan	
Supplier A										
Porridge oats	11.01	8.34	12.09	1.82	77.76	60.71	0.35	9.19	9.15	1.19
Oats flour	9.56	8.33	12.41	1.90	77.35	60.28	0.23	9.91	8.96	1.29
Burghol	11.41	2.62	14.65	1.23	81.50	61.82	0.16	4.30	0.19	0.94
Wheat flour	12.05	2.16	12.40	0.98	84.46	69.67	1.93	3.26	0.41	0.69
Supplier B										
Porridge oats	11.34	8.33	12.32	1.91	77.45	58.35	0.35	9.81	9.17	1.31
Oats flour	12.11	8.15	11.65	1.52	78.68	63.55	0.35	8.14	8.02	0.97
Burghol	10.46	2.40	13.88	1.27	82.46	60.05	0.35	4.15	0.28	0.97
Wheat flour	12.26	2.06	12.22	0.82	84.90	71.33	2.33	3.04	0.49	0.55
Mean	11.27	5.30	12.70	1.43	80.57	63.22	0.76	6.48	4.58	1.00

[a] Data was calculated on dry matter basis.
[b] Calculated by difference; carbohydrate = [total solids - (protein + fat + ash)]
Results are average of two determinations performed on each sample.

oats and barley. The protein content (~12 g 100 g^{-1}) of porridge oats, oats flour and wheat flour (suppliers A and B) were similar, but lower than that of Burghol (~14 g 100 g^{-1}), and the over all average was 12.7 g 100 g^{-1}. The total carbohydrate content averaged 80.6 g 100 g^{-1}, and the highest values (84.9 g 100 g^{-1}) was found in wheat flour (supplier B) and the lowest (77.4 g 100 g^{-1}) in oats flour (supplier A). The ash content of all the cereals used ranged between 0.82 and 1.91 g 100 g^{-1}.

Principal Component Analysis was used to map-out the main differences in gross chemical composition of different cereals used, and the results are shown in Figure 5.1. The PCs were visualised on two-dimension and accounted for 93.2%. The first PC accounted for 66.8% and the second PC for 26.4% of the variance. Vector loading of the data for chemical composition showed clear differences between the cereals. For example, the Burghol from both suppliers were associated with the protein, whilst the wheat flours were high in total carbohydrate. However, the fat and ash content were related to Porridge oats and oats flours (supplier A and B). The variance loaded on PC 1 discriminated the oats products from the Burghol and/or wheat flour. Thus, the fat and ash content of cereals were negatively correlated with protein and carbohydrate, whilst positive correlation was found between: (a) the fat and ash, and (b) the protein and carbohydrate.

The result of carbohydrate-based content (starch, free sugar, fibre, β-glucan) and phytic acid is also shown in Table 5.2. It is evident that the starch content of porridge oats and oats flour (supplier A) and Burghol (supplier B) were similar (~ 60 g 100 g^{-1}). While the concentration of free sugars of porridge oats (supplier A and B), oats flour and Burghol (supplier B) were the same (*i.e.* 0.35 g 100 g^{-1}).

The enzymatic gravimetric method used for dietary fibre analysis (see section 3.8.1.7) may not provide a true measure of dietary fibre because the method is based on simulated digestion of the sample using enzymes, followed by weighing the residue which may include resistant starch and/or insoluble constituent such as Maillard reactions. Thus, the results obtained were higher than expected (see sections 4.2.1 and 4.3.2), and it was decided to measure the dietary fibre as non-starch polysaccharide using enzymatic method as described in section 3.9.1.7. As illustrated in Table 5.2, the mean value of dietary fibre

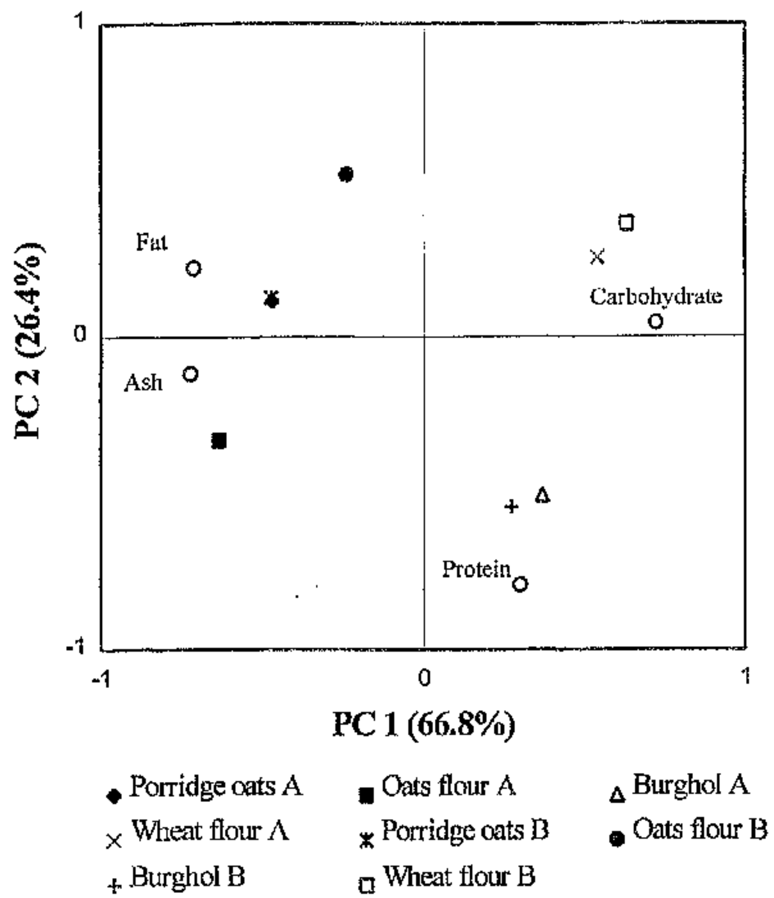


Figure 5.1 Principal Component biplot of chemical composition of different cereals.

was 6.5 g 100 g^{-1}, and similar amounts (~4 g 100 g^{-1}) was found in both Burghols (suppliers A and B), but the highest amount (9.9 g 100 g^{-1}) was found in oats flour (supplier A) and the lowest (~ 3 g 100 g^{-1}) for wheat flours.

All the porridge oats and oats flours were rich in β-glucan (~ 8.8 g 100 g^{-1}) compared to Burghols and wheat flours (0.34 g 100 g^{-1}). The mean value of β-glucan for all the cereals was 4.6 g 100 g^{-1}. Phytic acid content in these cereals were relatively similar to Burghols (supplier A and B) and oats flour (supplier B) (Table 5.2). However, the highest values of phytic acid (1.3 g 100 g^{-1}) was found in porridge oats (supplier B), and the lowest (0.6 g 100 g^{-1}) in wheat flour (supplier B).

PCA was performed on carbohydrate-based content to analyse the differences between the cereals, and a biplot was produced for the data matrix (see Figure 5.2). Two-dimensional solution accounted for 97.9% where PC 1 accounted for 82.8% and the PC 2 for 15.1%. Three main groups appeared, the porridge oats and oats flours (supplier A and B) were clustered near to each other and were associated with the fibre, β-glucan and phytic acid content. The wheat flours (suppliers A and B) were grouped together because they contained high starch and free sugar content. However, the group associated with the Burghol samples appeared deficient in carbohydrate-based content when compared to the other cereals. It can be observed from vector angles that the starch and free sugar contents of the cereals are strongly correlated with each other and negatively correlated with phytic acid. The fibre and β-glucan content were highly correlated with each other and positively correlated with phytic acid.

5.2.2 Mineral contents

The mineral contents of different cereals are shown in Table 5.3. The calcium content concentration of 60 mg 100 g^{-1} was found to be similar to both Burghols, oats flour (supplier A) and porridge oats (supplier B). The highest amount of calcium (70 mg 100 g^{-1}) was found in porridge oats (supplier A) and the lowest (30 mg 100 g^{-1}) in both wheat flours; the mean value of all the cereals was 51.3 mg Ca 100 g^{-1}. Phosphorus content (mg 100 g^{-1}) ranged between 190 and 460 for wheat flour (supplier B) and oats flour (supplier

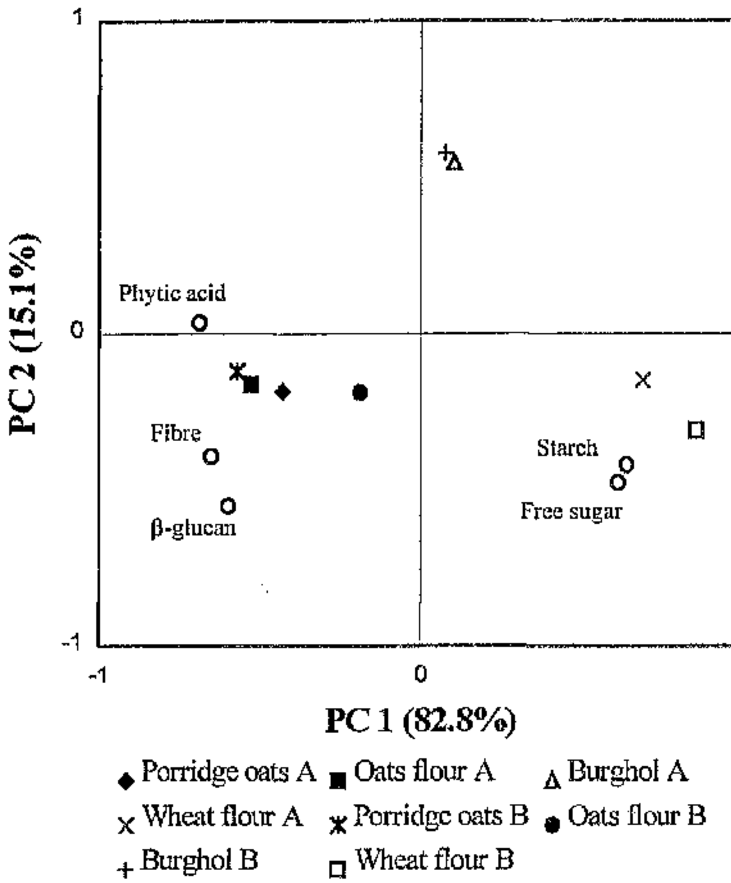


Figure 5.2 Principal Component biplot of carbohydrate-based content of different cereals.

Table 5.3 Mineral contents (mg 100 g^{-1})[a] of different cereals.

Sample	Ca	P	Mg	K	Na	Cu	Zn	Fe	Mn
Supplier A									
Porridge oats	70	350	140	252	4	0.42	2.74	4.68	5.10
Oats flour	60	460	140	392	3	0.44	2.73	3.77	5.00
Burghol	60	270	90	308	8	0.41	2.30	4.84	1.96
Wheat flour	30	230	60	259	3	0.35	1.74	1.36	1.36
Supplier B									
Porridge oats	60	450	140	405	4	0.31	2.45	3.86	4.39
Oats flour	40	360	100	332	3	0.29	2.59	5.44	4.69
Burghol	60	280	90	296	8	0.42	2.33	3.93	1.76
Wheat flour	30	190	50	223	4	0.27	1.34	1.65	0.45
Mean	51.3	323.8	101.2	308.4	4.1	0.36	2.3	3.7	3.1

[a] Data was calculated on dry matter basis.

Results are average of two determinations performed on each sample.

A), respectively, while the overall average was 323.8. The highest concentration of Mg (140 mg 100 g^{-1}) was found in porridge oats (supplier A and B) and oats flour (supplier A), and the lowest (50 mg 100 g^{-1}) in wheat flour (supplier B). Porridge oats (supplier B) contained highest amount of K (405 mg 100 g^{-1}), and wheat flour (supplier B) the lowest (223 mg 100 g^{-1}). In terms of Na, similar amount (3 mg 100 g^{-1}) was found in porridge oats, oats flours and wheat flour; however, the Burghol contained 8 mg 100 g^{-1} of sodium.

The Cu content (~ 0.4 mg 100 g^{-1}) in the cereals (supplier A and Burghol supplier B) was similar, but slightly lower amounts were found in oats flour and wheat flour from supplier B. Zn content (*ca.* ≥ 2.3 mg 100 g^{-1}) was also the same in all the samples except the wheat flour (1.3 - 1.7 mg 100 g^{-1}). Also, the Mn content (5 mg 100 g^{-1}) was slightly higher in all oats products than the wheat products (< 2 mg 100 g^{-1}). Appreciable amount of iron (≥ 4 mg 100 g^{-1}) was found in all the cereal products except wheat flour. Lower amount of iron in wheat flour than those to wheat bran and/or kernel was reported by Holland *et al.*, (1991), and the overall average of iron was 3.6 mg 100 g^{-1} (see Table 5.3).

PCA was used to differentiate the cereals according to their mineral contents, and the results are shown in Figure 5.3. The variance was portrayed on two-dimensional plot and accounted for 79.7% (*i.e.* PC 1 = 62.5% and PC 2 = 17.2%). Again, the cereals are clearly separated into three groups. A large group associated with porridge oats and oats flour because they have high contents of Mg, P, K, Mn, Zn, Fe and Ca. A second group comprised of Burghols due to high Cu content, and the third group consisted of wheat flours which were deficient in mineral contents compared to other types of cereals.

5.2.3 Microbiological quality

The microbiological quality of different cereals is shown in Table 5.4. Total colony count ranged between $1.5x10^3$ and $1.9x10^5$ cfu g^{-1}, and these counts indicate microbial contamination during processing. Coliforms were not recovered from any of the cereal samples at the dilution tested, *i.e.* 10^{-1}. The yeasts and moulds were only recovered from porridge oats (supplier A), and oats flour and wheat flour (supplier B); the counts were $1.5x10^2$, $1.6x10^2$ and $1.1x10^2$ cfu g^{-1}, respectively. However, aerobic spore-formers (*i.e.*

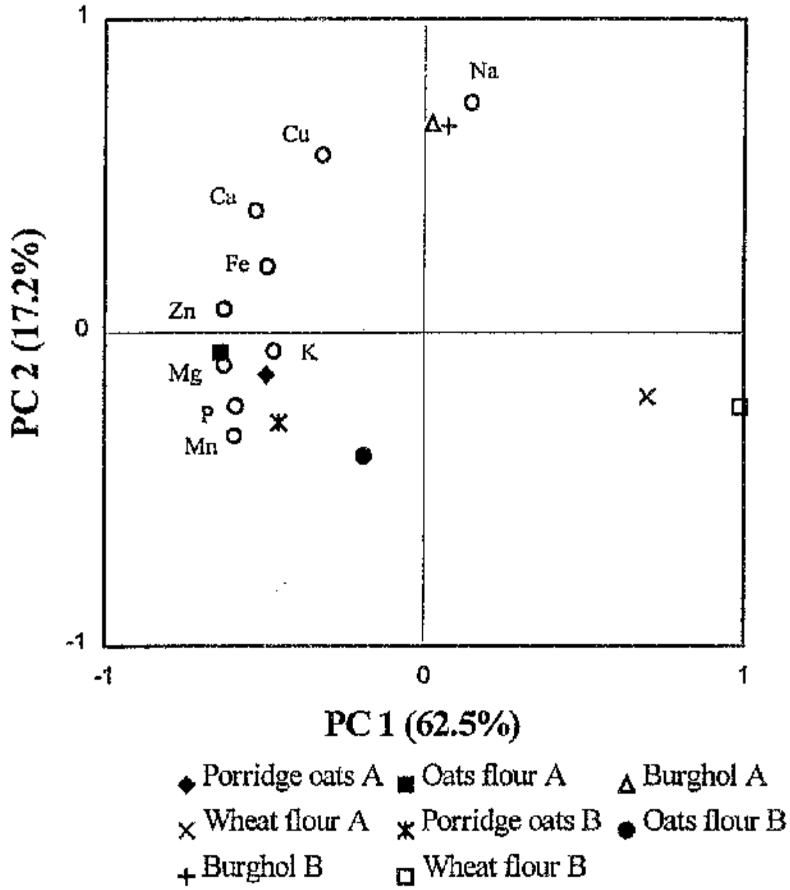


Figure 5.3 Principal Component biplot of mineral contents of different cereals.

Table 5.4 Microbiological quality (cfu g^{-1})[a] of different cereals.

Cereal	Total colony count	Coliforms	Yeasts and moulds	Aerobic spore-formers	
				Mesophiles	Thermophiles
Supplier A					
Porridge oats	1.5×10^4	<10[b]	1.5×10^2	2.2×10^2	<10
Oats flour	2.4×10^4	<10	<10	1.9×10^2	2.9×10^2
Burghol	4.1×10^4	<10	<10	8.7×10^3	1.1×10^4
Wheat flour	1.3×10^4	<10	<10	4.2×10^3	<10
Supplier B					
Porridge oats	3.9×10^4	<10	<10	2.2×10^2	<10
Oats flour	1.9×10^5	<10	1.6×10^2	<10	<10
Burghol	2.2×10^4	<10	<10	8.2×10^3	3.9×10^3
Wheat flour	1.5×10^3	<10	1.1×10^2	<10	<10

[a] Results are average of single sample plated in duplicate.
[b] No growth at 10^{-1} dilution.

mesophilics) were evident in most of the cereals, and the counts ranged between 1.9×10^2 and 8.7×10^3 cfu g^{-1} (Table 5.4). Only oats and wheat flours (supplier B) were low in mesophilic spore-formers count (<10 cfu g^{-1}). However, the thermophilic spore-formers counts were only recovered from the three samples [*e.g.* oats flour (supplier A) and Burghols (supplier A and B)], and the counts were 2.9×10^2, 1.1×10^4 and 3.9×10^3 cfu g^{-1}, respectively. The presence of thermophilic spore-formers in Burghol confirms similar results on previously tested Burghol (see Table 4.8).

5.3 Production of Kishk using different cereals with various acidulants and 'milk'

Kishks made with different types of Burghol (oats, barley or wheat) were different and influenced the sensory quality of the product (Tamime *et al.*, 1997b). The perceived sensory attributes such as aroma, flavour and mouth feel characters differentiated these Kishks from porridge oats. Nevertheless, oats are widely used in Scotland, and thus, porridge oats and oats flour were compared with Burghol and wheat flour as cereal additives in Kishk-making to study the effect of type of cereals and grain size on the quality of the product. Furthermore, since porridge is consumed as gruel prepared with milk, Kishk was made using 'milk' rather than yoghurt; the efficacy of the role of the starter organisms on the flavour of the product was also studied where direct acidified milk using GDL was compared *per se* with yoghurt. A total of two trials (*i.e.* 48 batches) were used to produce Kishk as described in Figure 3.6 using four types of cereals (*i.e.* porridge oats, oats flour, Burghol, and wheat flour). The Kishk made from non-fermented milk was produced by mixing the 'milk' with the cereals and dried without the secondary fermentation stage in view to control and minimise the undesirable microbial growth originating from the cereal (see Table 5.4). However, Kishks made with GDL milk and yoghurt were subjected to six days secondary fermentation similar to the traditional method of production (Tamime and O'Connor, 1995).

5.3.1 Compositional quality of Kishk

The average chemical composition of the 24 Kishk samples is shown in Table 5.5, and the individual trial results are illustrated in Appendix VIII. The influence of acidulants and

Table 5.5 Chemical composition (g 100 g^{-1})[a] of Kishk made from different cereals, acidulants and 'milk'.

Cereal base	Moisture			Fat			Protein			Carbohydrate			Ash			Salt		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Porridge oats	8.64	9.15	9.09	10.65	8.66	10.49	19.23	18.74	19.48	66.46	66.59	63.88	3.66	6.02	6.16	-[e]	3.21	3.23
Oats flour	8.32	9.55	10.02	9.35	8.66	9.84	19.59	18.68	19.14	67.44	66.75	64.89	3.63	5.92	6.13	-	3.16	3.20
Burghol	9.54	9.21	9.11	5.85	3.72	6.70	21.22	20.17	21.07	69.45	70.32	66.11	3.48	5.81	6.13	-	3.22	3.23
Wheat flour	12.06	10.18	8.37	5.58	3.55	6.49	19.70	18.77	21.29	71.47	72.08	65.86	3.26	5.60	6.37	-	3.19	3.24
SED[f]		0.48			0.28			0.31			0.34			0.09			0.02	
Treatment effect[g]																		
Cereal type		***			***			***			***			**			ns	
'Dairy' base[h]		ns			***			***			***			***			***	
Supplier x cereal type		***			**			ns			***			ns			ns	
Supplier x 'dairy' base		*			ns			ns			ns			ns			*	
Cereal type x 'dairy' base		***			***			***			***			***			ns	
Supplier x cereal type x 'dairy' base		ns			***			ns			***			ns			ns	

[a] Data was calculated on dry matter basis. [b] 'Milk'. [c] GDL. [d] Yoghurt. [e] No salt added.

[f] Standard error of difference of mean.

[g] Significance; ns = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

[h] 'Dairy' base is referred to as b, c or d.

Results are average of cereals supplied from two sources and 'dairy' base, of two trials and two determinations performed on each sample .

'milk' on the gross composition of the Kishk was evident. The moisture content ranged between 8.1 and 12.5 g 100 g^{-1}, and due to the variation in moisture content of Kishk, the data was calculated on a dry matter basis (DMB) for comparison purposes. The fat, protein, carbohydrate and ash content [g 100 g^{-1} (DMB)] ranged between 3.6 and 10.7 (SED = 0.28), 18.7 and 21.3 (SED = 0.31), 63.9 and 72.1 (SED = 0.34) and 3.3 and 6.4 (SED = 0.09), respectively. These results were similar to those reported for the Lebanese commercial Kishk (see Table 4.3). However, variation in the chemical composition of the product was influenced by the type of cereal used (Table 5.2). The fat content in oats-based Kishk was higher than those made with Burghol or wheat flour, whilst all the Kishks made with GDL milk contained lower fat content when compared with the other Kishk products despite the fact that the milk originated from one batch. Such effect could be largely influenced by the action of GDL in milk. As soon as the GDL was added to the milk, the pH dropped instantaneously from 6.6 to 6.2 and later to 5.14 within 1 h; by contrast the starter culture activity required more than 3 h to reach pH 5.4 (data not shown). As a consequence, a rapid and coarser gel was formed when GDL was used which resulted in the entrapment of the fat globules in the protein matrix. Such complexed structure interfered with the complete extraction of the fat component from the product leading to lower fat measurement in the Kishk. A similar observation was reported by Ibrahim *et al.* (1994) when Labneh was made from cultured milk and direct acidification. In the former product the fat content [g 100 g^{-1} (DMB)] averaged 41.7, whilst in Labneh made from acidified milk averaged 37.4. Thus, it is evident that the lower fat content in Kishk made with GDL milk is an analytical artefact. Also the Kishk made from porridge oats contained slightly more fat than similar products made from oats flour (see Table 5.2 and 5.5). The analysis of Kishks made with GDL milk were repeated to confirm the results, and no significant differences were found.

The variation in the ash content in all the different types of Kishk were influenced by: (a) the type of the cereal used (see Table 5.2), and (b) the amount of added salt. It can be observed that Kishks made with 'milk' did not contain Na Cl (Table 5.5), whilst the other products contained ~ 3.2 g 100 g^{-1} (DMB) salt (SED = 0.02). The reasons for not adding salt to such type of Kishk were as follow: *firstly*, the primary objectives of adding salt in Kishk were to control the rate of acid production by starter culture during the secondary fermentation stage, and *secondly*, to mask or partially neutralise the acidic taste in the product. Thus, since Kishk made with 'milk' was not subjected to the secondary fermentation stage and did not contain any acid(s), it was decided not to add salt. Furthermore, the addition of salt to such Kishks render them to become more salty in taste, and preliminary trials using the sensory panel were required to find the appropriate amount of salt to be added to produce Kishk similar in saltiness to a product made with either cultured or GDL milk with added salt. Incidentally, the Kishks made with no added salt could be similar in taste to a traditional Scottish porridge.

Analysis of variance (Table 5.5) showed significant differences ($P < 0.001$) for fat, protein, carbohydrate, ash and salt of Kishk for 'dairy' base used. While the treatment effects between cereal type x 'dairy' base were significant ($P < 0.001$) for fat, protein, carbohydrate and ash but not salt. However, the supplier x cereal type effects was only significant for carbohydrate ($P < 0.001$) and fat ($P < 0.01$). Whilst the differences between supplier x cereal type x 'dairy' base were significant ($P < 0.001$) for fat and carbohydrate.

Principal Component Analysis was performed to calculate the relationship between the Kishk made with different cereals, acidulants and 'milk', and the results are shown in Figure 5.4. A biplot on the various analytical data was produced, and the first two PCs accounted for 79.91% of the variance (PC 1 = 46.9% and PC 2 = 33.3%). In order to observe the clear differences between the variables, the biplot was split into two sub-plots (*i.e.* 5.4A and 5.4B). The data loaded on PC 2 separated the Kishk according to the type of cereal used as a baseline (*i.e.* oats-based and wheat-based; Figure 5.4A), whilst the data loaded on PC 1 grouped the Kishk according to the acidulants and 'milk' used (Figure 5.4B). The carbohydrate and protein contents of the Kishk are strongly correlated with each other and negatively correlated with fat content. This axis (fat *versus* protein and carbohydrate) is the main feature of the Figure 5.4. Oats-based Kishks are higher in fat, and lower in protein and carbohydrate content than wheat-based Kishks (Figure 5.4A).

Within both product groups, yoghurt based-Kishk has the highest fat content while GDL-based Kishk has the lowest (Figure 5.4B). A second axis defined by the salt and ash contents of the Kishk is at right angles to the axis defined by fat, protein and carbohydrate.

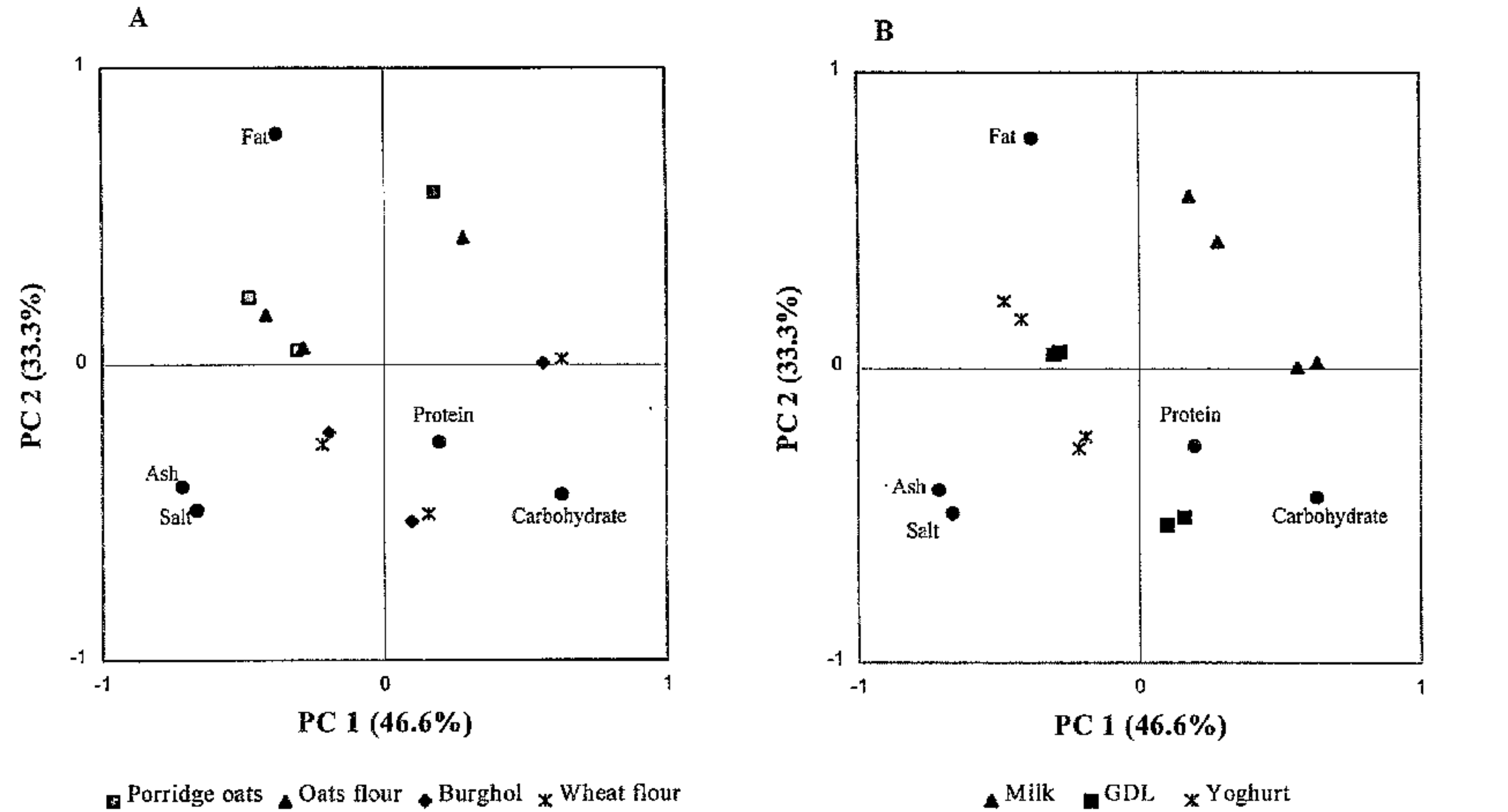


Figure 5.4 Principal Component Analysis of chemical composition of Kishk made with different cereals, acidulants and `milk` using a correlation matrix.

The ash and salt content of the Kishks are highly correlated with each other. Kishks made from 'milk' are lower in salt and ash than those made with yoghurt or GDL (Figure 5.4B), which is as expected because salt was not added to any of the former products.

5.3.2 Carbohydrate-based content

Carbohydrate-based content of the different samples of Kishk is shown in Table 5.6, and the individual trial results are shown in Appendix IX. These components varied in the Kishks produced mainly due to the type of cereal used (see Table 5.2). The starch content in all the products averaged 40 g 100 g^{-1} (SED = 0.8); wheat flour averaged 70 g 100 g^{-1}, whilst the rest of the cereal contained ~ 61 g 100 g^{-1} (see Table 5.2). Thus, as a consequence, the product made with wheat flour, should in theory, contain the highest amount of starch; such experimental anomaly was difficult to explain. Nevertheless, the results of starch content of Kishk were similar to those reported by Tamime *et al.* (1997b).

The average free sugar content of wheat-based Kishk made with 'milk' or GDL was ~14 g 100 g^{-1} which was slightly higher (~13 g 100 g^{-1}) than oats Kishk made with similar 'dairy' bases. Both of these cereal-based Kishks made with yoghurt appeared to be low in free sugar concentration (*i.e.* ~9 g 100 g^{-1}). Such low free sugar content in yoghurt-based Kishk could be the consequence of starter organisms which metabolised the lactose in milk for their growth during the fermentation stage.

The dietary fibre (*i.e.* analysed as non-starch polysaccharide - see section 3.8.1.7) content of oats-based Kishks were higher (*ca.* 5.8 g 100 g^{-1}) when compared with wheat-based Kishks (see Table 5.6) with the exception of products made with Burghol (~ 6.6 g 100 g^{-1}). The fibre content in Burghol is lower than those in oats which makes it difficult to explain the apparent higher fibre content in the Burghol-based Kishk.

It is of interest to note that the level of β-glucan content averaged 3 g 100 g^{-1} in oats-based Kishk as compared to < 1 g 100 g^{-1} in wheat-based products. These results are similar to levels of β-glucan in Kishk reported by Tamime *et al.* (1997b). Such appreciable level of

Table 5.6 Carbohydrate-based content (g 100 g^{-1})[a] of Kishk made from different cereals, acidulants and 'milk'.

Cereal base	Starch			Free sugar			Fibre			β-glucan			Phytic acid		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Porridge oats	40.04	39.86	41.85	13.16	12.91	9.77	6.42	5.96	6.21	2.28	3.55	2.89	0.67	0.64	0.58
Oats flour	41.35	40.24	40.99	13.20	12.29	9.14	5.35	5.74	4.95	1.63	3.33	2.52	0.66	0.64	0.46
Burghol	39.43	35.52	39.36	12.77	12.77	10.47	6.76	6.41	6.73	0.26	1.44	0.99	0.68	0.59	0.66
Wheat flour	42.73	38.47	42.73	15.81	16.06	7.76	2.99	2.99	3.19	0.55	0.55	1.56	0.40	0.13	0.15
SED[e]		0.80			0.27			0.36			0.11			0.03	
Treatment effect[f]															
Cereal type		***			***			***			***			***	
'Dairy' base[g]		***			***			ns			***			***	
Supplier x cereal type		***			ns			ns			*			***	
Supplier x 'dairy' base		ns			***			ns			ns			ns	
Cereal type x 'dairy' base		**			***			ns			***			***	
Supplier x cereal type x 'dairy' base		*			***			ns			***			**	

[a] Data was calculated on dry matter basis. [b] 'Milk'. [c] GDL. [d] Yoghurt.

[e] Standard error of difference of mean.

[f] Significance; ns = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

[g] 'Dairy' base is referred to as b, c or d.

Results are average of cereals supplied from two sources and 'dairy' base, of two trials and two determinations performed on each sample .

β-glucan in these products may suggest that these products represents an enhanced nutritional value in the human diet.

Phytic acid content of the Kishks made with oats and Burghol averaged 0.6 g 100 g^{-1}, and the products made with wheat flour averaged ~ 0.2 g 100 g^{-1}. These lower amounts of phytic acid in these products could be attributed to low amounts found in wheat flour (see Table 5.2) and similar amounts of phytic acids content in Kishk have been reported by Tamime *et al.* (1997b). The lower content of phytic acid in Kishk made with yoghurt could be due to catalytic action of phytase produced by micro-organisms during the fermentation stage (Kent and Evers, 1994).

The influence of different treatment effects on the carbohydrate content of Kishks was statistically calculated by univariate analysis, and the results are shown in Table 5.6. Significant difference ($P < 0.001$) was noted for starch, free sugar, fibre, β-glucan and phytic acid content for cereal type and for 'dairy' base (with exception of fibre). While differences between supplier x cereal type was only significant for starch, phytic acid ($P < 0.01$) and β-glucan ($P < 0.05$). However, cereal type x 'dairy' base effect was significant ($P < 0.001$) for free sugar, β-glucan and phytic acid, and for starch ($P < 0.01$), and significant differences were for supplier x cereal type x dairy base for free sugar, β-glucan ($P < 0.001$), phytic acid ($P < 0.01$), and starch ($P < 0.05$).

Even though univariate analysis showed differences between the Kishks that were influenced by the different treatment effects, it was difficult to resolve the main differences between the Kishks into product groupings. Multivariate analysis was also used to highlight the main differences between the Kishks. Thus, PCA biplot (Figure 5.5) of the Kishks described by their carbohydrate content was produced and accounted for 75.2% of the variation of the original 5 variables, (PC1 = 44.7% and PC2 = 30.5%). The biplot was split into two sub-plots (Figure 5.5A and 5.5B) in order to explain the differences between variables. Two main groups of Kishk were separated along the axis defined by fibre and phytic acid content of the product. The larger cluster of Kishk contained the porridge oats-based, oats flour-based and Burghol-based Kishks, and was higher in fibre and phytic acid than the wheat flour-based Kishk. The larger cluster of Kishk can be further segregated

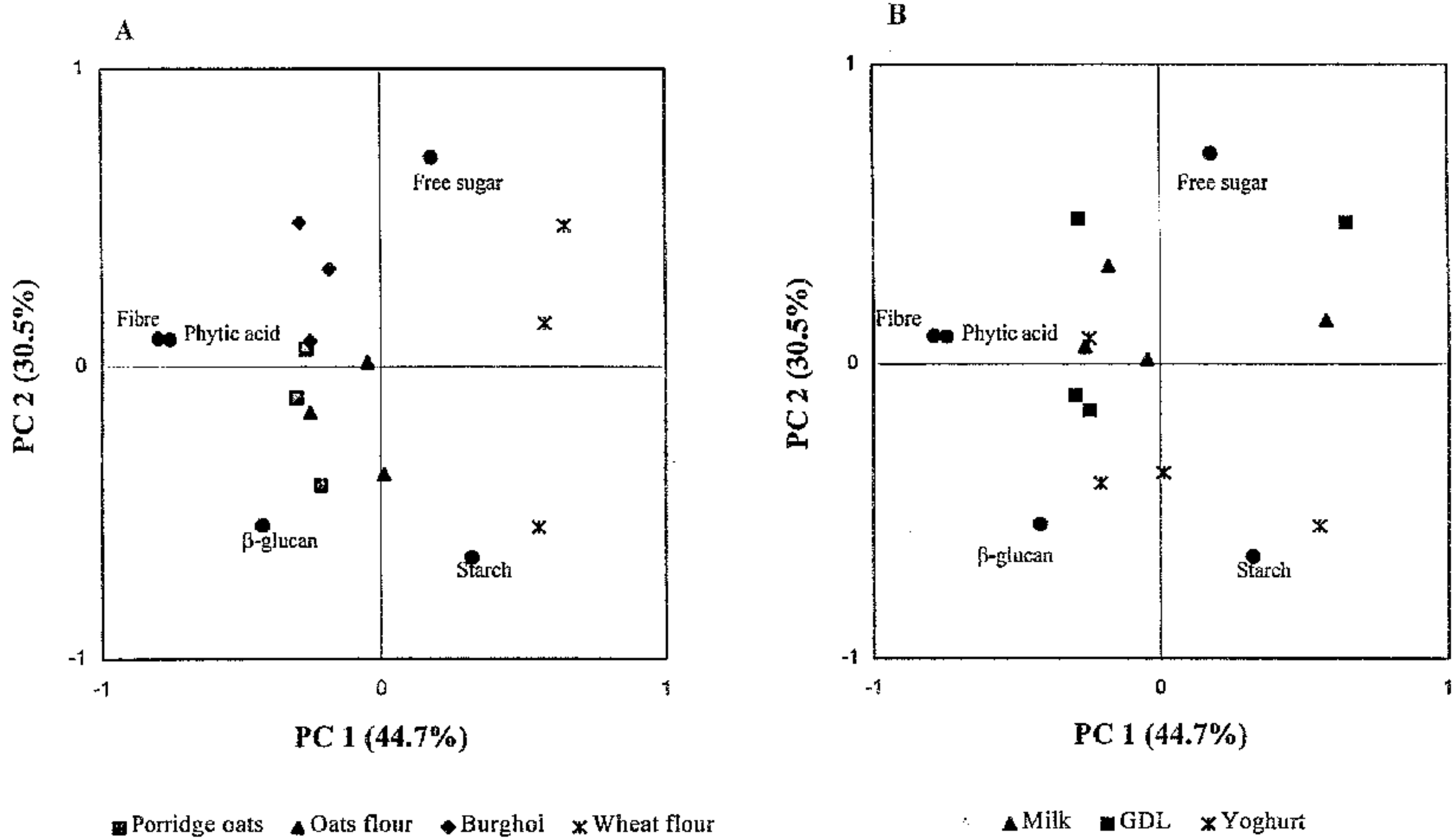


Figure 5.5 Principal Component Analysis of carbohydrate-based content of Kishk made with different cereals, acidulants and `milk` using a correlation matrix.

into oats-based and Burghol-based Kishks. The latter products were higher in free sugar content and lower in starch and β-glucan content than those of oats-based Kishks (Figure 5.5A). While the grouping according to the 'dairy' base showed that the higher amount of starch and β-glucan was associated with yoghurt-based Kishk, whilst the free sugar content belongs to both GDL and 'milk'-based Kishks (Figure 5.5B). The starch was negatively correlated with fibre, phytic acid and free sugar, and positively correlated with β-glucan.

5.3.3 Mineral contents

Mineral contents of Kishk were analysed and slight variation in proximate concentration was evident (Table 5.7 and Appendix X). In all the yoghurt- or GDL-based Kishks, the Na content was ~ 1174 mg 100 g^{-1} which was higher than the Kishks made with 'milk' (~ 146 mg 100 g^{-1}); the variation could be attributed to the salt which was not added in the latter products. Appreciable amount (mg 100 g^{-1}) of Ca (460), P (611), Mg (113), K (776), Zn (4), Fe (4) and Mn (3) were found in Kishk made with oats than those made with wheat (456, 495, 89, 728, 3, 2, and 0.95, respectively) (SED = 13.7, 26.9, 3.9, 14.9, 0.11, 0.35, and 0.05, respectively). Cu content (0.33 mg 100 g^{-1}) in wheat-based Kishk was slightly higher than oats-based Kishk (0.27 mg 100 g^{-1}). The reason(s) for such differences in the mineral contents of Kishk is mainly attributed to the mineral contents of the cereal used (see Table 5.3). In general, the mineral concentration in all the Kishks was relatively similar to those reported by Tamime *et al.* (1997b) with the exception of K and Fe.

Analysis of variance showed significant differences ($P < 0.001$) for P, Mg, K, Zn, Fe and Mn depending of the type of cereal used. Differences in the 'dairy' base used was for K, Na, Zn ($P < 0.001$), Mg, Mn ($P < 0.01$), Ca and Fe ($P < 0.05$); however, treatment effects between supplier x cereal base was for Mg, Mn ($P < 0.001$), and P and K ($P < 0.05$). The treatment effect for cereal type x 'dairy' base was only significant for Fe ($P < 0.001$) and Zn ($P < 0.05$).

PCA was used to examine the relationship between these Kishks, and the data matrix of the mineral contents was visualised on two-dimensional representation. The proportion of variance accounted for 84.2% (*i.e.* 64.5% for PC 1 and 19.7% for PC 2). Biplots were

Table 5.7 Mineral contents (mg 100 g^{-1})[a] of Kishk made from different cereals, acidulants and 'milk'.

Cereal base	Ca			P			Mg			K			Na			Cu			Zn			Fe			Mn		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Porridge oats	472.5	455.0	457.5	617.5	592.5	610.0	117.5	112.5	117.5	790.2	756.5	784.0	148.2	1130	1155	0.26	0.25	0.24	3.83	3.35	3.53	4.18	3.89	3.76	3.07	3.02	3.10
Oats flour	467.5	445.0	460.0	612.5	630.0	600.0	112.5	110.0	110.0	790.7	747.2	784.7	149.0	1173	1170	0.33	0.26	0.26	4.01	3.48	3.77	5.37	3.65	3.78	3.15	2.99	3.14
Burghol	457.5	455.0	472.5	525.0	480.0	530.0	100.0	95.0	102.5	741.5	735.0	759.7	145.7	1208	1193	0.30	0.28	0.49	3.31	3.05	3.25	2.65	2.53	3.12	1.24	1.19	1.26
Wheat flour	445.0	430.0	475.0	472.5	450.0	512.5	77.5	72.5	87.5	701.0	680.5	752.5	141.5	1135	1230	0.22	0.21	0.48	2.63	2.67	3.04	1.18	1.45	2.11	0.63	0.63	0.73
SED[e]		13.68			26.95			3.87			14.87			41.89			0.12			0.11			0.35			0.05	
Treatment effect[f]																											
Cereal type		ns			***			***			***			ns			ns			***			***			***	
'Dairy' base[g]		*			ns			**			***			***			ns			***			*			**	
Supplier x cereal type		ns			*			***			*			ns			ns			ns			ns			***	
Supplier x 'dairy' base		ns			ns			ns			ns			ns			ns			ns			ns			ns	
Cereal x 'dairy' base		ns			ns			ns			ns			ns			ns			*			***			ns	
Supplier x cereal type x 'dairy' base		ns			ns			ns			ns			ns			ns			ns			ns			ns	

[a] Data was calculated on dry matter basis. [b] 'Milk'. [c] GDL. [d] Yoghurt.

[e] Standard error of difference of mean.

[f] Significance; ns = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

[g] 'Dairy' base is referred to as b, c or d.

Results are average of cereals supplied from two sources and 'dairy' base, of two trials and two determinations performed on each sample .

constructed and the data were divided into two groups: *firstly*, product based on the type of cereal, and *secondly*, the product based on 'milk' or acidulant used. The Kishks were mapped into four groups (see Figure 5.6A), and the largest group of Kishks were associated with porridge oats and/or oats flour. A similar grouping can be also observed with respect to the 'dairy' bases used (*i.e.* milk, yoghurt or GDL) (Figure 5.6B). The remaining three groups consisted of pairs of Kishks made from wheat products. Unlike the oats products, the pairs did not align with the type of 'dairy' base used except for yoghurt (Figure 5.6B). The largest group was rich in P, K, Zn, Fe, Mg and Mn, while Ca, Na and Cu contents were higher in Burghol based-Kishk (see Figure 5.6A). Wheat flour-based Kishks were deficit in mineral contents compared with other products.

5.3.4 Analysis of organic acids

Organic acids contents of different acidulants, 'milk' and Kishks (milk, GDL and yoghurt) were analysed, and Table 5.8 shows the mean values of such acids in these products. Appendix XI and XII show the organic acids content of each individual trial. The pattern of increase or decrease of organic acids content in yoghurt was mainly influenced by the metabolic activity of *Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus*. The main feature was a large increase in lactic and acetic acids after fermentation when compared with the milk base. There are some data available on the organic acids contents of yoghurt that has been reported by Marsili *et al.* (1981), Bevilacqua and Califano (1989), Barrantes (1993) and La Torre (1997), but no data is available on direct acidified milk made with GDL. However, in the present study the following observations could be made:

- A portion of the orotic, citric, acetic and hippuric acids content were utilised during chemical acidification.
- Pyruvic acid was totally disappeared in direct acidified milk.
- Lactic and uric/formic acids were slightly increased.
- Propionic acid in all the 'dairy' bases was not detected which confirm the observations reported by Barrantes (1993) and La Torre (1997).

PCA (Figure 5.7) was performed on the different acidulants (GDL and yoghurt) and 'milk' used for Kishk-making. Since there are only 3 'dairy' bases, 100% of the information in the

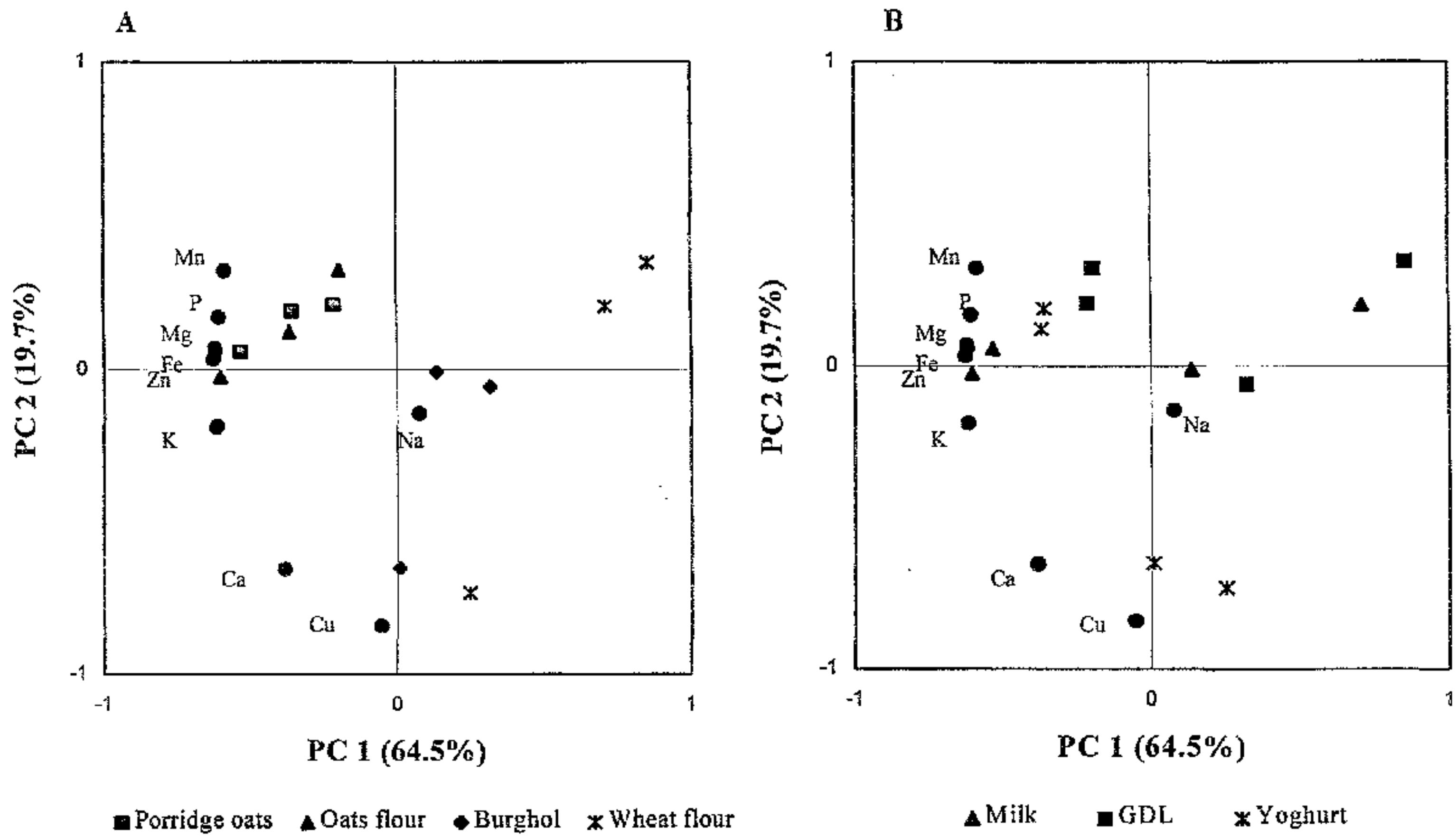


Figure 5.6 **Principal Component Analysis of mineral contents of Kishk made with different cereals, acidulants and `milk` using a correlation matrix.**

Table 5.8 Organic acids contents ($\mu g\ g^{-1}$) of acidulants (GDL and yoghurt), 'milk' and Kishks[a].

Organic acids	'Dairy' base				Kishk			
	'Milk'	GDL	Yoghurt	SED[b]	'Milk'	GDL	Yoghurt	SED[b]
Orotic	61.6	54.1	55.1	1.97	31.0	10.3	11.7	1.6
Citric	886.1	818.8	720.4	45.40	45.2	20.9	53.9	8.4
Pyruvic	5.3	0.0	26.8	2.18	3.8	8.0	12.1	3.3
Lactic/gluconic	189.9	198.6	7147.2	155.40	120.0	5056.0[c]	9547.0	923.1
Uric/Formic	14.5	17.5	24.2	0.70	19.1	20.1	22.4	6.3
Acetic	16.9	8.9	130.1	8.32	95.0	1559.0	209.0	281.3
Propionic	-[d]	-	-	-	397.0	1379.0	411.0	402.9
Hippuric	10.8	8.0	5.3	1.02	16.0	14.8	19.5	7.4

[a] Results are average of two trials and of two determinations performed on each sample.
[b] Standard error of difference of mean.
[c] Mainly gluconic acid.
[d] Not detected.

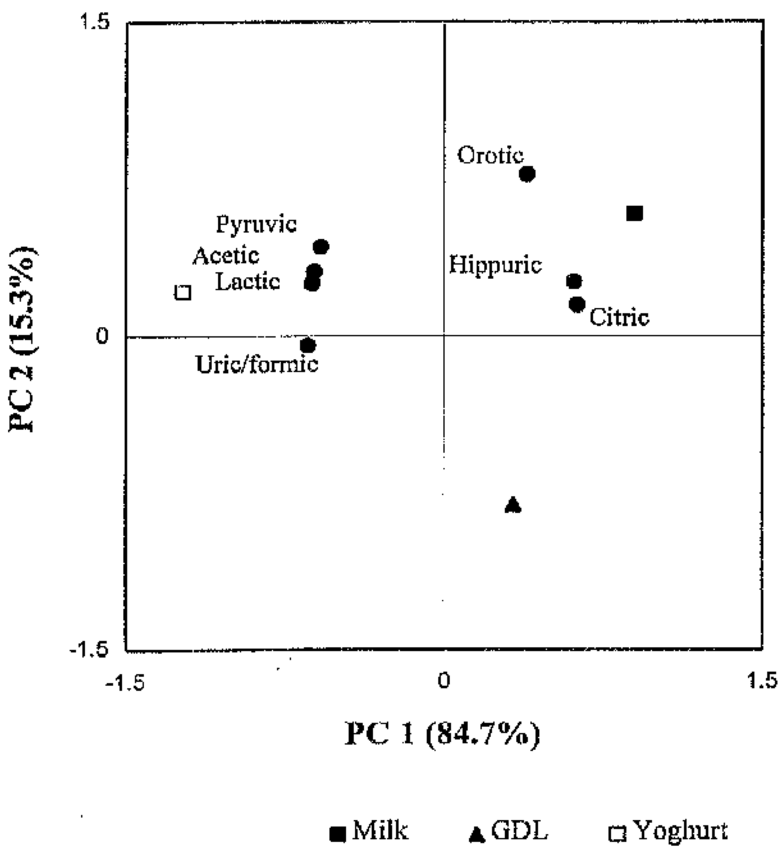


Figure 5.7 Principal Component Analysis of organic acids contents of different acidulants (GDL and yoghurt) and `milk` used for Kishk-making.

correlation matrix for the organic acids can be summarised by two PCs. PC 1 and 2 accounted for 84.7% and 15.3%, respectively, of the variance and contrasted yoghurt with 'milk' and GDL. Yoghurt was found to be rich in pyruvic, acetic, lactic and uric/formic acids; the 'milk' was high in orotic, hippuric and citric acids; GDL was found to be deficient in some organic acids when compared with the other bases (see Table 5.8).

The analysis of Kishk showed that there was a slight variation in organic acids profile of Kishk made with different types of cereals (see Table 5.9). For instance, The concentration ($\mu g\ g^{-1}$) of orotic (20), citric (43), lactic (5170) and propionic (886) were slightly higher in oats-based Kishk compared to wheat-based Kishk (15, 38, 4645 and 573, respectively) (SED = 1.2, 5.3, 666 and 258, respectively). Whilst slightly higher concentration ($\mu g\ g^{-1}$) of pyruvic (11), uric/formic (25), acetic (760) and hippuric (17) was found in wheat-based Kishk when compared with oats-based Kishk (5, 16, 482 and 16, respectively) (SED = 2.4, 4.2, 197 and 5.1, respectively).

The influence of 'dairy' base on Kishk was the major factor (see Table 5.8); the 'milk'-based Kishk was low in orotic, citric, pyruvic and lactic acids, and high in uric/formic, acetic and hippuric acids that contrast to the milk from which it has been made, while propionic acid was synthesised. This change in organic acids contents could be the influence of the drying process and/or cereal type. Furthermore, the organic acids contents were higher in fermented Kishk (GDL- or yoghurt-based) compared with 'milk'-based Kishk with exception of orotic, and citric and hippuric acids. Lactic acid was the only major acid in highest amount of yoghurt-based Kishk, but it was lower than that of previous experiment (see Table 4.14). The reason may be the growth of propionic acid bacteria which might have utilised some of the lactic acid to form propionate. However, in GDL-based Kishk three main acids appeared to be present. Lactic/gluconic acid content (5056 $\mu g\ g^{-1}$) was the highest followed by acetic acid (1559 $\mu g\ g^{-1}$) and propionic acid (1379 $\mu g\ g^{-1}$) (see Table 5.8) compared with the 'milk' base which could be the result of dissociation of gluconic acid and possibly the residual bacteria present in the milk (Marsili *et al.*, 1981).

Organic acids produced during fermentation are likely to influence the taste and flavour of

Table 5.9 Significance of treatment effects on the organic acids contents ($\mu g\ g^{-1}$) of Kishk made from different cereals, acidulants and 'milk'.

Organic acids	Kishk		SED[a]	Treatment effect[b]		
	Oats-based	Wheat-based		C[c]	D[d]	CxD
Orotic	19.9	15.4	1.2	***	***	***
Citric	42.6	37.5	5.3	*	***	ns
Pyruvic	5.2	10.7	2.4	***	***	***
Lactic/gluconic	5170.0	4645.0	665.6	ns	***	ns
Uric/Formic	15.6	25.4	4.2	***	ns	ns
Acetic	481.5	760.0	196.6	*	***	*
Propionic	885.5	573.0	258.4	**	***	ns
Hippuric	16.3	17.3	5.1	ns	ns	ns

[a] Standard error of difference of mean.
[b] Significance; ns = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.
[c] Cereal type. [d] 'Dairy' base ('milk', GDL and yoghurt).
Results are average of oats-based and wheat-based Kishks, of two trials and two determinations performed on each sample .

the product, and the microbial action on the milk and cereal constituents may, consequently, affect the texture of the final product (El-Sadek *et al.*, 1958; Marsili *et al.*, 1981). Consequently, the combined level of organic acids contents and microbial activity in Kishk during secondary fermentation stage could enhance specific flavour characteristics in the product.

Analysis of variance shows that significant differences between the cereal-based Kishk for orotic, pyruvic, uric/formic ($P < 0.001$), propionic ($P < 0.01$), citric and acetic acids ($P < 0.05$), but not for lactic or hippuric acids. Also significant differences ($P < 0.001$) were found in Kishk made with different 'dairy' bases for orotic, citric, pyruvic, lactic, acetic and propionic acids, but not for uric/formic and hippuric acids. There was no significant differences in organic acids with exception of uric/formic ($P <0.05$) of Kishk made with cereals from different suppliers. However, significant differences were found for lactic/gluconic acid ($P < 0.001$) and propionic acids ($P < 0.01$) of the Kishk based on the treatment effect of supplier x 'dairy' base. Furthermore, the differences in organic acids of Kishk (*i.e.* cereal x 'dairy' base) was only significant for orotic, pyruvic ($P < 0.001$) and acetic acids ($P < 0.05$). However, the other treatment effects (suppliers x cereal x 'dairy' base) were not significant except for citric acid ($P < 0.05$) (Data not shown).

PCA was applied to the organic acids contents of Kishks, and the variance was encompassed by the first two PCs which accounted to 69.3% [PC 1 (38.2%) and PC 2 (31.1%); see Figure 5.8)]. However, to visualise the main differences, the biplot was split into two sub-plots (Figure 5.8A and 5.8B), and the angles between the vectors representing the variables (*i.e.* orotic, citric, pyruvic, lactic, uric/formic, acetic, propionic and hippuric acids) are approximations to the correlation between each variable. Hence, variables with small angles (< 90°) between them are positively correlated, those with large angles (> 90) are negatively correlated, and those with right angles (90°) are un-correlated. Three groups in organic acids contents were evident with respect to cereal type, and each group contained all the types of cereals used for Kishk-making (Figure 5.8A). Such grouping indicated a very mild effect of cereal-base on the type of Kishk. However, the groups in the bipilot with respect to 'dairy' base ('milk', yoghurt and/or GDL) separated the Kishks according to their organic acids contents (Figure 5.8B). 'Milk'-based Kishk was notably

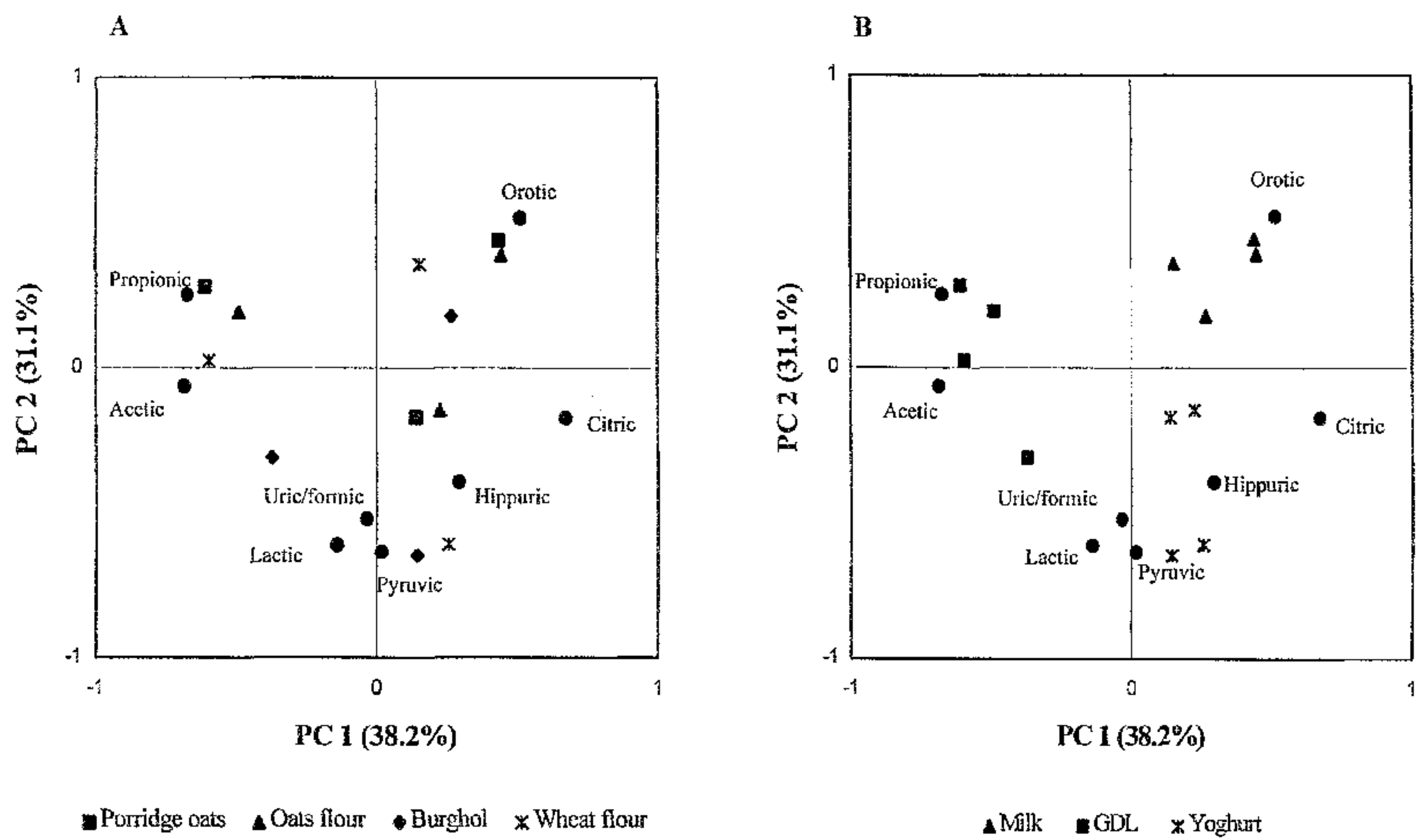


Figure 5.8 Principal Component Analysis of organic acids contents of Kishk made with different cereals, acidulants and `milk` using a correlation matrix.

low in most of the organic acids contents except orotic acid, and yoghurt-based Kishk showed high content of citric, hippuric, uric/formic pyruvic and lactic acid, whilst GDL-based Kishk was found rich in gluconic, propionic and acetic acids.

5.4 Microbiological quality of Kishk

5.4.1 Microbiological analysis of Kishk (fresh and stored)

The results of the microbiological quality of Kishk samples when fresh and stored are shown in Tables 5.10, and the individual trial results are shown in Appendix XIII. Total colony counts (cfu g^{-1}) of non-lactic acid bacteria in fresh product were recovered within the range between 2.6×10^4 and 3.6×10^6 cfu g^{-1}. Similar counts were reported by Atia and Khattab (1985), Al-Mashhadi *et al.* (1987) and Tamime (unpublished data). It is most likely that these organisms originated from the cereals (Table 5.4) because the milk base was subjected to high heat treatment, but not the cereals. In general, no significant increase or decrease in the total count was found during the storage period (6 and 12 months) of Kishk made with 'milk' or GDL with the exception of Burghol-based Kishk (GDL) (see Table 5.10). The non-lactic acid bacteria in yoghurt-based Kishk decreased gradually during the 12 months storage period. These results indicate that: (a) non-lactic acid bacteria do not grow in dried product containing ≤ 10 g 100 g^{-1} moisture, and (b) the presence of organic acids produced by starter culture may have inhibited the survival of these undesirable organisms.

In all the Kishks (fresh and stored) no coliforms and/or yeasts and moulds were recovered at 10^{-1} dilution. However, in some occasions the growth of yeasts and moulds in oats-based Kishk (fresh) was evident (see Table 5.10), but not the stored products. Thus, the inherent characteristic of Kishk (*i.e.* dried and acidic) may have inhibited the yeasts and moulds.

It is interesting to note that the count of aerobic spore-formers in 'milk'-based and fermented (GDL- and yoghurt-based) Kishks was relatively similar (Table 5.10). The presence of these in Kishk is not surprising as these micro-organisms are heat resistant,

Table 5.10 Microbiological quality (cfu g^{-1})[a] of Kishk made from different cereals, acidulants and 'milk'.

Cereal base/ storage time	Total colony count			Coliforms			Yeasts and moulds			Aerobic spore-formers: Mesophiles			Aerobic spore-formers: Thermophiles		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Fresh															
Porridge oats	$1.3x10^6$	$3.5x10^4$	$1.5x10^5$	<10[e]	<10	<10	<10	$2.6x10^2$	$1.7x10^3$	$1.1x10^2$	$2.7x10^2$	$2.0x10^2$	$2.8x10^2$	$2.9x10^2$	$1.9x10^2$
Oats flour	$1.7x10^6$	$4.2x10^4$	$3.1x10^4$	<10	<10	<10	<10	$7.5x10^2$	$1.1x10^2$	$2.7x10^2$	$3.0x10^2$	$1.9x10^2$	$1.6x10^2$	$2.0x10^2$	<10
Burghol	$3.2x10^6$	$8.0x10^5$	$2.2x10^6$	<10	<10	<10	<10	<10	<10	$6.2x10^3$	$3.9x10^2$	$5.8x10^3$	$1.8x10^3$	$1.5x10^3$	$4.1x10^3$
Wheat flour	$3.7x10^5$	$2.6x10^4$	$2.7x10^4$	<10	<10	<10	<10	<10	<10	$6.0x10^3$	$2.2x10^3$	$1.3x10^3$	<10	<10	<10
6 Month															
Porridge oats	$1.2x10^6$	$3.1x10^4$	$8.8x10^4$	<10	<10	<10	<10	<10	<10	$1.4x10^3$	$2.0x10^3$	$1.8x10^3$	$3.1x10^2$	$2.1x10^2$	$1.2x10^2$
Oats flour	$1.1x10^6$	$2.6x10^4$	$3.6x10^4$	<10	<10	<10	<10	<10	<10	$2.6x10^2$	$5.5x10^2$	$1.1x10^3$	$1.6x10^2$	$1.5x10^2$	<10
Burghol	$2.8x10^6$	$6.7x10^4$	$9.9x10^5$	<10	<10	<10	<10	<10	<10	$8.4x10^3$	$3.2x10^3$	$4.7x10^3$	$5.6x10^3$	$4.1x10^3$	$4.2x10^3$
Wheat flour	$1.9x10^5$	$4.7x10^4$	$1.9x10^4$	<10	<10	<10	<10	<10	<10	$8.0x10^2$	$4.7x10^3$	$1.4x10^3$	<10	<10	<10
12 Month															
Porridge oats	$8.7x10^5$	$4.8x10^4$	$1.9x10^4$	<10	<10	<10	<10	<10	<10	$2.5x10^2$	$2.7x10^3$	$1.1x10^3$	$1.4x10^3$	$2.4x10^2$	$1.4x10^2$
Oats flour	$1.9x10^6$	$5.0x10^4$	$1.8x10^3$	<10	<10	<10	<10	<10	<10	$1.9x10^2$	$2.1x10^2$	$2.0x10^2$	$1.3x10^3$	<100	$1.3x10^2$
Burghol	$1.5x10^6$	$2.0x10^4$	$1.9x10^4$	<10	<10	<10	<10	<10	<10	$5.3x10^3$	$2.9x10^3$	$4.2x10^3$	$6.3x10^3$	$5.4x10^2$	$5.5x10^3$
Wheat flour	$3.1x10^5$	$3.6x10^4$	$8.0x10^3$	<10	<10	<10	<10	<10	<10	$8.5x10^2$	$2.1x10^3$	$3.8x10^3$	<10	$1.2x10^2$	$1.8x10^2$

[a] Results are average of two trials of single sample plated in duplicate of Kishk made with different cereals supplied from two sources and 'dairy' bases. [b] 'Milk'. [c] GDL. [d] Yoghurt. [e] No growth at 10^{-1} dilution.

tolerate high drying temperatures, and are most likely to be present in cereals (Table 5.4) and/or SMP (see Table 4.1). There was no considerable change in counts of these organisms even after storage period (6 and 12 month). Once again, the nature of the Kishk (*i.e.* acidic, low moisture and presence of salt) might have contributed towards the proliferation of these spore-formers in the product.

5.4.2 Enumeration of starter organisms (fresh and stored)

The starter culture, MY 087, was used for the production of yoghurt for Kishk-making (see section 4.1.3), thus, the initial inocculum, as expected, contained similar counts of *Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus* (*i.e.* 1.3×10^{11} cfu g^{-1} and 2.2×10^{8} cfu g^{-1}, respectively). However, the survival of these organisms in Kishk were examined in fresh and stored (6 and 12 month) products, and the counts are summarised in Table 5.11; Appendix XIV shows the individual trial results. The total count of *Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus* (cfu g^{-1}) in fresh products ranged between 1.6×10^{3} and 1.6×10^{6}, and 9.0×10^{2} and 4.5×10^{5}, respectively. In general, Burghol-based Kishk showed the highest viable counts of the yoghurt organisms than the other cereal-based Kishks. While the counts of *Str. thermophilus* decreased marginally after 6 and 12 months storage period in wheat-based, but non survived in oats-based Kishk after 12 months period. A similar pattern was also observed for *Lb. delbrueckii* subsp. *bulgaricus* except the Kishk made with wheat flour and stored for 12 months (Table 5.11). It is difficult to explain such microbial behaviour; however, the oats-based products may contain inhibitory substance(s) such as fatty acids that affected the survival of these organisms in Kishk stored > 6 months.

5.5 Organoleptic evaluation

The sensory quality of the Kishks had notable differences in most of the characters of odour, flavour, after-taste and mouth feel were associated with type of 'dairy' base used (Table 5.12). For example, in contrast to Kishk made with yoghurt, the product made with 'milk' was very much more *creamy, fruity/sweet, intensity* (odour and flavour), *cereal* and *cardboard* (odour, flavour and after-taste), whilst less *acid* (odour, flavour and after-taste), and *salty, apple, bitter* (flavour). The GDL-based Kishk had slightly higher scores for

Table 5.11 Enumeration of starter organisms (cfu g^{-1}) of Kishk[a] made from different cereals and yoghurt.

Kishk sample	*Str. thermophilus*			*Lb. delbrueckii* subsp. *bulgaricus*		
	Fresh	6 month	12 month	Fresh	6 month	12 month
Porridge oats	$6.8x10^3$	$6.1x10^3$	<10	$1.5x10^3$	<10	<10
Oats flour	$1.6x10^3$	$7.0x10^2$	<10	$9.0x10^2$	<10	<10
Burghol	$1.6x10^6$	$5.2x10^5$	$8.0x10^3$	$4.5x10^5$	$2.6x10^5$	$1.5x10^3$
Wheat flour	$8.2x10^3$	$6.0 x 10^3$	$4.4x10^3$	$3.6x10^3$	$2.5x10^2$	<10

[a] Results are average of two trials of single sample plated in duplicate of Kishk made with different cereals supplied from two sources and yoghurt base.

Table 5.12 Effect of different cereal products (Porridge oats, oats flour, Burghol or wheat flour) and of the type of 'dairy' base on the sensory properties of Kishk.

Attribute	Porridge oats			Oats flour			Burghol			Wheat flour			SED[d]
	M[a]	D[b]	Y[c]	M	D	Y	M	D	Y	M	D	Y	
Odour													
Intensity	47.5	48.8	43.4	50.3	44.5	37.6	47.7	46.5	41.8	47.0	47.2	46.1	3.92
Creamy	30.6	14.3	19.2	34.2	12.0	12.9	25.5	14.1	17.3	26.0	11.5	11.5	3.35
Acid	5.7	29.8	22.6	2.7	27.7	19.8	9.8	26.5	18.9	10.1	33.0	31.0	4.83
Fruity/sweet	28.1	16.2	18.6	30.5	13.0	16.9	29.2	17.8	18.4	25.1	16.5	14.7	3.49
Cooked	42.4	42.1	38.4	43.5	37.7	32.1	38.0	40.7	34.0	40.8	39.3	34.0	3.92
Cereal	36.3	34.8	33.0	40.9	32.9	25.8	38.0	35.9	34.9	33.6	26.0	17.8	3.63
Cardboard	18.4	14.0	10.0	17.4	15.7	9.3	10.5	11.7	11.5	12.6	10.5	15.3	3.28
Flavour													
Intensity	48.5	53.9	57.6	43.1	52.8	58.1	48.9	53.3	57.7	48.1	50.7	61.0	4.34
Creamy	31.4	21.0	19.3	30.6	18.0	21.5	28.0	24.3	18.8	30.7	18.5	17.2	3.31
Acid	10.8	40.4	48.3	4.8	43.2	56.2	14.5	32.9	44.9	10.1	52.3	60.2	5.88
Fruity/sweet	27.1	16.9	20.1	25.4	18.1	25.2	28.0	28.1	26.2	35.5	23.9	21.4	3.56
Cooked	46.4	44.5	43.2	46.1	40.7	38.8	39.2	40.8	35.5	44.9	42.2	37.4	3.69
Cereal	42.0	37.6	35.4	38.5	36.3	34.4	48.6	45.8	41.9	33.8	29.1	26.6	3.50
Cardboard	28.3	16.2	18.8	27.6	21.0	20.0	19.7	11.0	14.2	21.4	23.0	22.0	3.67
Apple	4.3	10.1	8.0	0.5	8.1	11.6	2.3	6.6	13.8	3.4	7.3	6.9	2.41
Bitter	3.0	9.9	11.3	1.4	6.9	9.5	2.6	5.1	9.1	4.8	11.8	16.8	2.33
Salty	7.1	16.8	17.5	1.8	18.4	21.5	6.6	19.2	20.9	6.7	19.9	23.5	3.31
After-taste													
Intensity	40.8	42.0	43.5	38.0	43.4	48.0	42.9	42.0	45.8	39.5	51.6	58.4	2.66
Acid	8.3	30.4	36.7	2.8	33.7	43.5	8.7	24.9	40.6	7.3	44.9	51.6	4.36
Cereal	35.0	33.0	30.1	35.4	31.3	27.4	37.1	37.3	31.7	29.2	25.3	21.1	3.21
Cardboard	23.4	12.5	12.2	21.7	20.5	15.8	12.3	9.7	13.0	22.2	15.7	16.9	3.50
Mouth feel													
Viscosity	69.4	71.3	66.5	67.5	65.5	63.1	67.9	64.4	65.7	65.4	66.8	66.5	4.86
Chalky	33.3	29.0	31.6	39.7	27.6	24.4	56.0	56.7	54.9	21.8	17.3	20.0	4.04
Sticky	56.6	64.0	65.4	52.8	58.3	57.4	20.7	22.4	25.7	67.2	74.1	76.2	3.34
Slimy	23.0	30.1	29.8	16.4	29.4	29.0	2.7	3.5	4.2	52.3	64.2	70.3	4.71
Mouth-coating	45.8	48.7	49.8	47.8	47.9	47.1	40.6	37.9	42.2	46.6	49.9	54.5	3.66

[a] 'Milk'. [b] GDL. [c] Yoghurt.
[d] Standard error of difference of mean.

cereal (odour, flavour and after-taste), *cooked* (odour and flavour) and *acid* (odour) but less for *creamy* (odour), *acid* (flavour and after-taste), and *bitter, salty* (flavour) when compared with Kishk made with yoghurt. It is possible to suggest that the type of acidulant (*i.e.* GDL *versus* yoghurt) affected the sensory profile of the product. The mouth feel attribute of Kishk made with 'milk' perceived as slightly more *viscous* and *chalky* characters, while less *sticky, slimy* and *mouth-coating*. However, the Kishks made with GDL and yoghurt had similar mouth feel scores, but the latter product was perceived more *sticky, mouth-coating* and *slimy*; and these characters were influenced by the type of cereal used. There was no evidence of systematic differences in odour, flavour, (Except *fruity/sweet*) or after-taste (except *intensity*) being associated with cereal type. While appreciable differences were found between mouth feel characters (*chalky sticky, slimy*) these attributes associated with the cereal type.

PCA was performed to observe the main differences between the Kishks based on type of cereal or 'dairy' base, and a biplot (Figure 5.9) was constructed in a proportion of 56% of variance. Factor 1 (31%) of variance was very highly significant ($P < 0.001$) which was affected by the cereal type and the 'particle size' (*i.e.* rolled oats , flour (wheat or oats) and Burghol). However, Factor 2 was also highly significant ($P < 0.001$) due to cereal type and 'dairy' base (*i.e.* milk, GDL or yoghurt). The biplot was split into two sub-plots to observe clear differences between these variables. Sensory space maps were constructed from the sensory scores for each Kishk. The variables of oats-based Kishk (Figure 5.9A) loaded on Factor 1 were clustered close to zero on the central line indicating a linear independence between the variables. It is evident that oats-based Kishk had no treatment effect corresponding to cereal 'particle size' (*i.e.* rolled oats or oats flour). However, variables loaded on Factor 2 clearly separated the Kishks into three groups according to their 'dairy' base (*i.e.* milk, GDL or yoghurt; see Figure 5.9A). A different sensory space maps was observed for wheat-based Kishk (Figure 5.9B) where a highly significant effect of mouth feel characters which were influenced by the cereal 'particle size' (*i.e.* Burghol or wheat flour) when loaded on Factor 1 resulted in two main groups of Kishks. Group 1 associated with Kishk made with wheat flour, while group 2 belongs to Burghol-based Kishk. Also, variables loaded on Factor 2 were separated according to the 'dairy' base used ('milk', GDL and yoghurt; Figure 5.9B). Comparing the biplot of Kishks made from oats or wheat

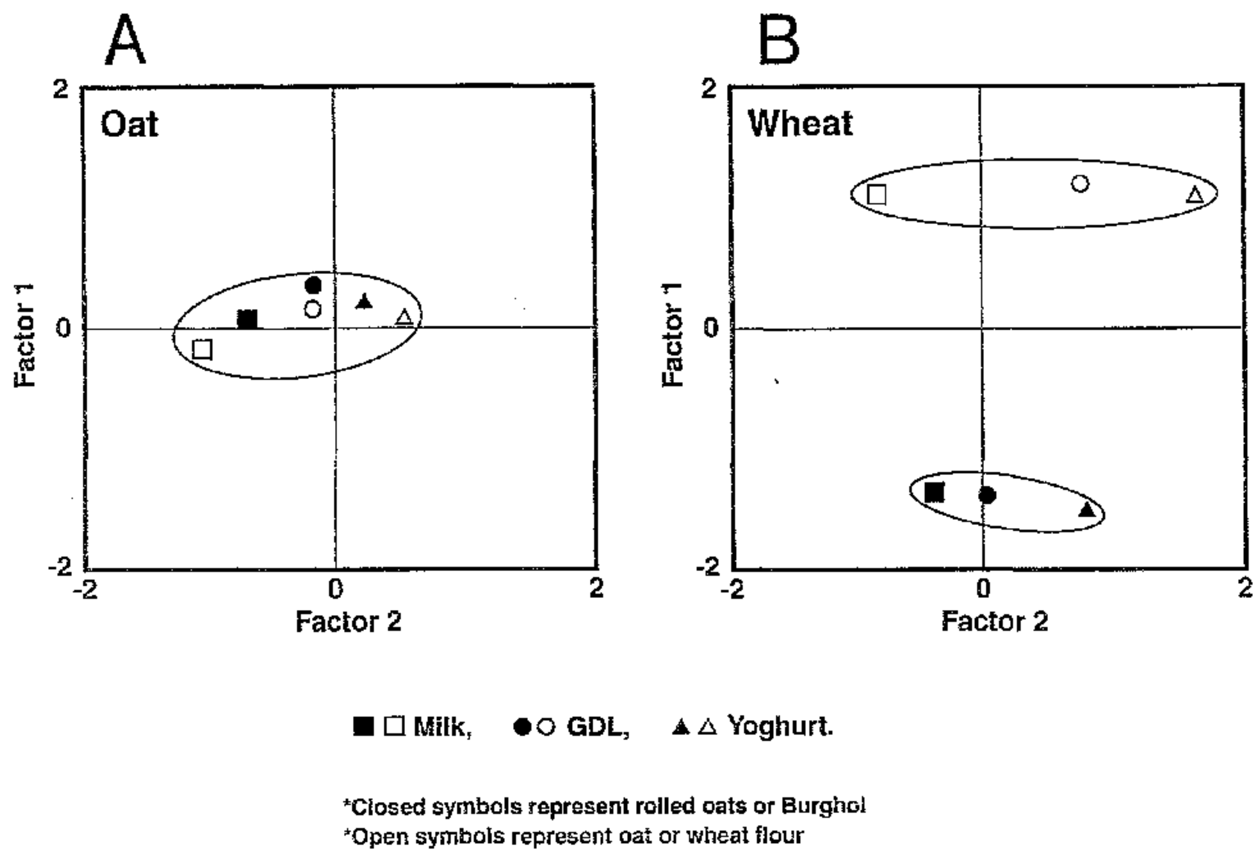


Figure 5.9 Principal Component biplot of sensory space maps of Kishk made with different cereals, acidulants and 'milk'.

(Figure 5.9A and 5.9B), the 'dairy' base had dominant effect, whilst the oats-based Kishks were clustered near the central line; the wheat-based Kishks were highly separated by sensory evaluation.

Interpretation of effect of cereal 'particle size' and/or type x 'dairy' base facilitated correlation matrix of the sensory attributes, and the variables loaded on biplot (Figure 5.10) showed a highly significant effect of mouth feel characters while the flavour and after-taste effects were milder. Attributes loaded on Factor 2 showed a clear separation into two groups: (a) a cluster grouped with the characters of after-taste and flavour close to the central line, and (b) a cluster group associated with characters of mouth feel. The latter group loaded on Factor 1 was again separated in opposite directions (see Figure 5.10). The flavour and after-taste characters perceived with oats-based Kishks were not distinctly separated in the sensory space when compared with products made from wheat. *Sticky* and *slimy* characters of the mouth feel were associated with wheat flour-based Kishks and the *chalky* character of mouth feel belongs to Burghol-based Kishk indicating the effect of cereal particle size, *i.e.* parboiled cracked wheat *versus* wheat flour.

Hence, to aid comparison of the effect of the cereal type on the perceived mouth feel characters of Kishk, star plot was constructed (Figure 5.11). Each attribute is assigned a vector, the length of which is determined by the magnitude of the attribute, expressed as a proportion of the maximum value within the sample set. The major variations in attributes were in *chalky, slimy* and *sticky* characters. Variation between the vector angles within the Kishks based on oats flour or wheat flour supplied from different sources were observed, while no appreciable differences between vector angles within the Kishks based on porridge oats or Burghol supplied from different sources were seen. A clear difference can be observed between vector angles of oats-based and wheat-based Kishks. Burghol-based Kishks contrasted quite differently to those made from wheat flour indicating the influence of the 'particle size' of cereals and method of preparation, *i.e.* parboiled cracked wheat *versus* wheat flour.

Nevertheless, there were clear indications from PCA that the effect of cereal 'particle size' x 'dairy' base was dominant in the sensory space. Thus, the differences in attributes were

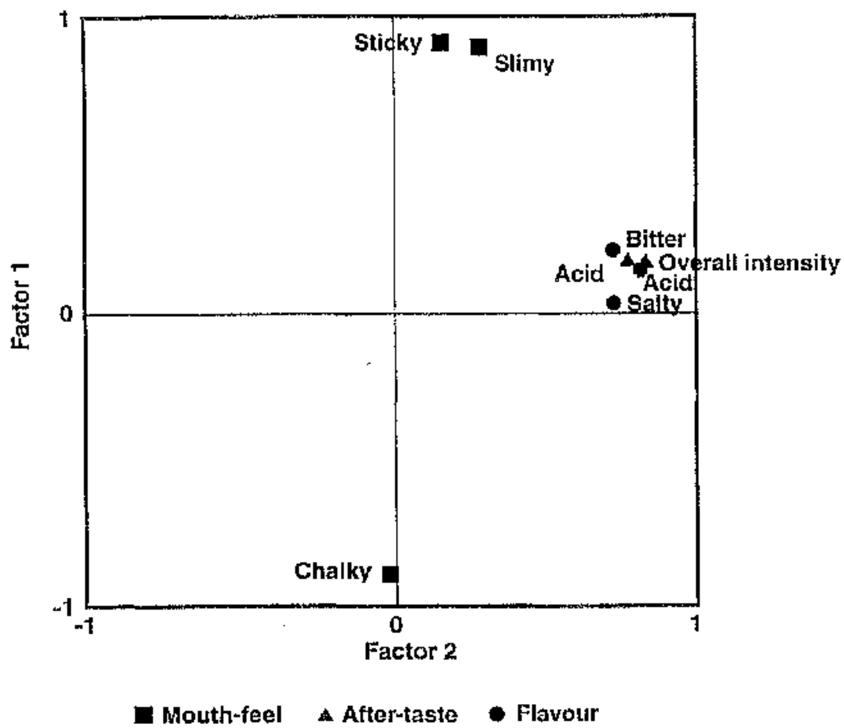
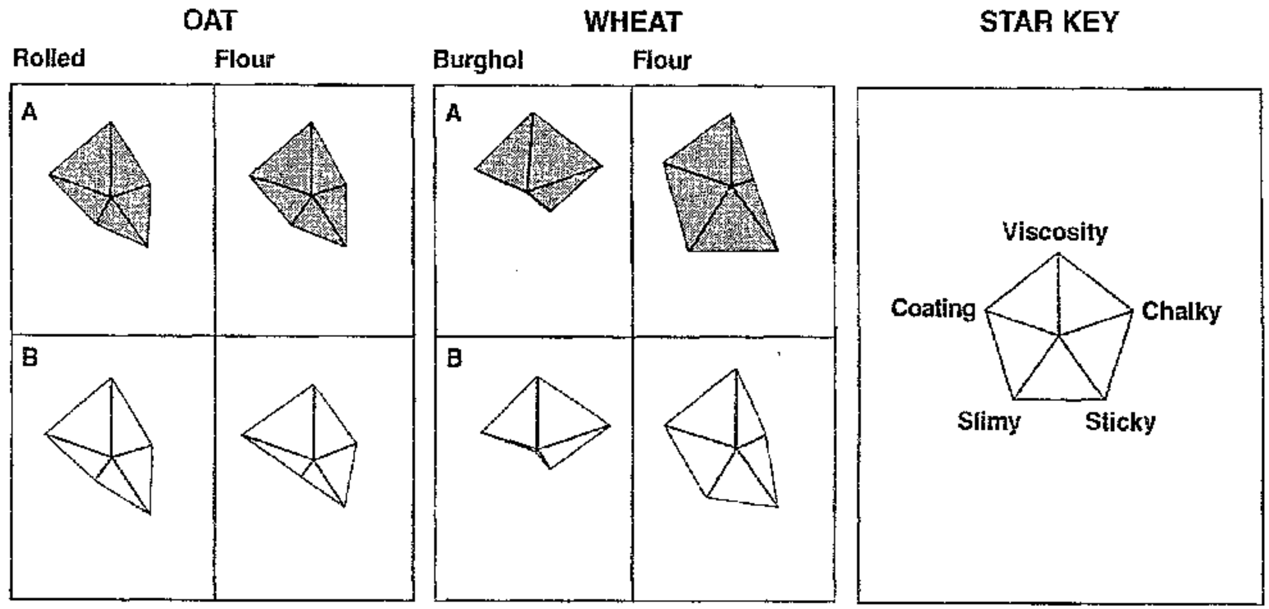


Figure 5.10 Principal Component biplot of sensory attributes of Kishk made with different cereals, acidulants and 'milk'.



A and B are different sources of oats and wheat products.

Figure 5.11 Star plots for the effect of cereal type on perceived mouth feel characters of Kishk.

examined by ANOVA, and significant treatment effects were found and are shown in Table 5.13. Significant treatment effect of the 'dairy' base was dominant in sensory characters, and the significant differences were found in: (a) odour [*creamy, acid, fruity/sweet, cereal*; ($P < 0.001$)], *intensity* and *cooked* ($P < 0.01$), (b) flavour [*intensity, creamy, acid, fruity/sweet, apple, bitter, salty* ($P < 0.001$), *cereal* ($P < 0.01$) and *cooked* ($P < 0.05$)], (c) after-taste [*intensity, acid, cereal* ($P < 0.001$) and *cardboard* ($P < 0.01$)], and (d) mouth feel [*sticky, slimy* ($P < 0.001$) and *chalky* ($P < 0.05$)]. The differences in the type of cereal used for Kishk-making was associated with mouth feel [*chalky, sticky* ($P < 0.001$) *slimy* ($P < 0.01$) and the *mouth-coating* ($P < 0.05$)], with after-taste [*intensity* ($P < 0.001$) and *acid* ($P < 0.05$)], with flavour [*fruity/sweet* ($P < 0.01$), *cooked* and *cardboard* ($P < 0.05$)] and with odour [*creamy* ($P < 0.05$)].

The differences between the cereals supplied by different sources was only evident for *intensity, cooked* (odour) and *slimy* (mouth feel) characters perceived at $P < 0.001$; *cooked, cardboard* (flavour) and *chalky* (mouth feel) characters at $P < 0.01$, and *acid* (odour) character at $P < 0.05$ (data not shown).

The effect of cereal 'particle size' was significantly dominant on mouth feel characters [*chalky, sticky, slimy* ($P < 0.001$)], *mouth-coating* ($P < 0.01$), and after-taste [*cereal* ($P < 0.001$), *intensity, acid* and *cardboard* ($P < 0.01$)]. However, significant effects of the following characters were also influenced by 'particle size' of the cereal: (a) *cereal* (odour, flavour and after-taste), (b) *cardboard* (flavour and after-taste), *intensity* and *acid* (after-taste), and (c) *acid* (flavour) characters were at $P < 0.001$, $P < 0.01$ and $P < 0.05$, respectively. The treatment effect of the type of cereal x 'dairy' base was only significant ($P < 0.05$) for *cardboard* (odour) and *fruity/sweet* (flavour), whilst the cereal x 'dairy' base x cereal 'particle size' was only significant for flavour attributes [*i.e. apple* ($P < 0.01$) and *fruity/sweet* ($P < 0.05$)] (data not shown).

The type of cereal x 'particle size' effect was highly significant on mouth feel (*chalky, sticky, slimy* and *mouth-coating*; $P < 0.001$), and on flavour (*cereal, apple* and *bitter*; $P < 0.001$); on odour and after-taste (*cereal*; $P < 0.01$ and *acid*; $P < 0.05$) and on after-taste (*intensity*; $P < 0.05$). The 'dairy' base x size of the cereal effect was only significant on

Table 5.13 Significant treatment effect on sensory attributes of Kishk made with oats and wheat products.

Attribute	Significance of treatment[a]				
	Cereal (C)	'Dairy' base[b] (D)	Size (S)	CxS	DxS
Odour					
Intensity	ns	**	ns	ns	ns
Creamy	*	***	ns	ns	ns
Acid	ns	***	ns	*	ns
Fruity/sweet	ns	***	ns	ns	ns
Cooked	ns	**	ns	ns	ns
Cereal	ns	***	***	**	**
Cardboard	ns	ns	ns	ns	ns
Flavour					
Intensity	ns	***	ns	ns	ns
Creamy	ns	***	ns	ns	ns
Acid	ns	***	*	ns	**
Fruity/sweet	**	***	ns	ns	ns
Cooked	*	*	ns	ns	ns
Cereal	ns	**	***	***	ns
Cardboard	*	ns	**	ns	ns
Apple	ns	***	ns	***	ns
Bitter	ns	***	ns	***	ns
Salty	ns	***	ns	ns	ns
After-taste					
Intensity	***	***	**	*	***
Acid	*	***	**	*	**
Cereal	ns	***	***	**	ns
Cardboard	ns	**	**	ns	ns
Mouth feel					
Viscosity	ns	ns	ns	ns	ns
Chalky	***	*	***	***	ns
Sticky	***	***	***	***	ns
Slimy	**	***	***	***	ns
Mouth-coating	*	ns	**	***	ns

[a] Significance; ns = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

[b] Referred to as 'milk', GDL and yoghurt.

intensity (after-taste; $P < 0.001$), *cereal* (odour; $P < 0.01$) and *acid* (flavour and after-taste; $P < 0.01$).

5.6 Production of Kishk using wheat products (Burghol, Burghol flour or flour) and 'dairy' base ('milk', GDL or yoghurt)

As shown from section 5.5, Kishk produced from different wheat product (Burghol or flour) showed significant treatment effect which was evident for mouth feel characters (*chalky, sticky, slimy* and *mouth-coating*). Probably the effect was associated with 'particle size' of the wheat flour or the Burghol. Thus, in view of such effect, the Burghol was milled into flour to make the particle size smaller for comparison purposes with wheat flour, and was used in this experiment for Kishk-making. A total of 18 batches of Kishk were produced as described in Figure 3.6 using different 'dairy' base ('milk', GDL or yoghurt).

5.6.1 Compositional quality

The average chemical composition of 18 samples of Kishks made with different wheat product, acidulants and 'milk' is shown in Table 5.14, and Appendix XV shows the results of Kishk made with wheat cereal supplied from different sources. Once again, the influence of acidulants and 'milk' on the gross composition of Kishk was evident, and variation in the various chemical component occurred. The moisture content ranged between 11.2 and 12.8 g 100 g^{-1}, hence, due to the variation in moisture content of Kishk, the data was calculated on dry matter basis for comparison purposes. The fat, protein, carbohydrate and ash content [g 100 g^{-1} (DMB)] ranged between 4.1 and 6.6, 19.3 and 22.5, 64.8 and 71.3, and 3.1 and 6.4, respectively. These results were in agreement of the previous experiment (see Table 5.5), and similar the Lebanese commercial Kishk (see Table 4.3). In general, the fat content in Burghol- and Burghol flour-based Kishks was relatively similar, but slightly higher than those made with wheat flour. Whilst the Kishks made with GDL contained lower fat content when compared with the other types of Kishk; the reason(s) was discussed elsewhere (see section 5.3.1).

Table 5.14 Chemical composition (g 100 g^{-1})[a] of Kishk made from different wheat products, acidulants and 'milk'.

Cereal base	Moisture			Fat			Protein			Carbohydrate			Ash		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Burghol	12.82	12.06	11.46	6.10	5.11	6.55	21.84	19.84	22.29	68.75	69.55	65.04	3.31	5.50	6.12
Burghol flour	12.44	12.68	11.15	6.07	5.34	6.46	21.95	20.34	22.52	68.67	68.85	64.83	3.31	5.47	6.19
Wheat flour	12.14	12.73	12.40	5.47	4.09	6.59	20.44	19.31	21.57	70.97	71.26	65.48	3.12	5.34	6.36

[a] Data was calculated on dry matter basis.
[b] 'Milk'. [c] GDL. [d] Yoghurt.
Results are average of cereals supplied from two sources and 'dairy' base, and two determinations performed on each sample .

The variation in the ash content in all the different types of Kishks was possibly influenced by: (a) the composition of the wheat cereal ingredients used (see Table 5.2), and (b) the amount of added salt.

5.6.2 Sensory quality

Inherent differences in the sensory quality of Kishk perceived from the 'particle size' of the wheat product (Burghol, Burghol flour and flour) were assessed by a panel of assessors using 26 discriminant attributes, and results are depicted in Table 5.15. In contrast to Burghol-based Kishk, Burghol flour-based Kishk was awarded slightly higher scores in most of the discriminant sensory characters, in particular the mouth feel (*viscosity, sticky, slimy* and *mouth-coating*). In wheat flour-based Kishk, higher scores were awarded by the panellist for mouth feel characters except for *chalky* character. These mouth feel characters could be influenced as a consequence, the broken/gelatinised starch either leached or degraded by amylases during the secondary fermentation period. Overall, flour-based Kishks were highly rated by the panellist for *acid* (odour, flavour and after-taste), *cardboard* (odour and flavour) and *bitter* (flavour), and these characters are normally regarded as undesirable to the Western palate (Muir *et al.*, 1995).

The influence of 'particle size' of wheat product was significantly dominant for mouth feel characters (Table 5.16); for example, *chalky, sticky, slimy* ($P < 0.001$) and *mouth-coating* ($P < 0.01$), whilst *viscosity* character was not significant. However, significant differences ($P < 0.001$, $P < 0.01$ and $P < 0.05$) were also perceived for *cereal* character of flavour, odour and after-taste, respectively and for *cardboard* character of after-taste ($P < 0.001$).

Effect of cereal supplied by different sources were significant in *cereal* and *cardboard* (flavour) characters at $P < 0.001$ and $P < 0.01$, respectively, *creamy* (odour and flavour), *cardboard* (odour and after-taste), *chalky* and *mouth-coating* (mouth feel) at $P < 0.05$. While the effect of 'dairy' base used for Kishk-making was dispersed in the characters of odour, flavour, after-taste and mouth feel, significant differences ($P < 0.001$) were found for *acid, cereal* (odour, flavour and after-taste), *creamy* (odour), *apple, bitter, salty* (flavour) and *intensity* (after-taste). While differences in *slimy* (mouth feel), and in

Table 5.15 Effect of different wheat products (Burghol, Burghol flour or flour) on the sensory properties of Kishk.

Attribute	Treatment effect (0-100)			SED[a]
	Burghol	Burghol flour	Wheat flour	
Odour				
Intensity	37.4	37.6	41.8	4.06
Creamy	17.3	17.8	14.2	2.81
Acid	19.0	18.6	26.4	3.80
Fruity/sweet	16.3	23.2	17.5	5.84
Cooked	27.7	31.1	28.6	3.79
Cereal	25.1	26.3	17.3	2.37
Cardboard	9.4	10.5	10.7	2.10
Flavour				
Intensity	49.3	47.9	53.0	5.60
Creamy	22.3	27.4	21.5	5.34
Acid	34.1	34.3	43.1	4.38
Fruity/sweet	23.8	26.2	20.9	4.41
Cooked	34.5	36.3	34.6	2.49
Cereal	36.7	37.3	22.2	1.16
Cardboard	16.2	18.5	18.1	3.07
Apple	8.5	8.1	5.7	1.14
Bitter	12.0	10.9	12.7	1.32
Salty	19.5	15.1	15.8	2.82
After-taste				
Intensity	40.2	40.7	44.9	3.51
Acid	44.3	42.2	46.6	2.32
Cereal	29.4	29.6	35.6	2.71
Cardboard	33.1	31.7	18.6	2.51
Mouth feel				
Viscosity	44.0	50.3	57.3	5.66
Chalky	54.3	49.6	22.7	2.42
Sticky	14.0	19.6	64.2	3.29
Slimy	3.9	6.5	49.7	2.47
Mouth-coating	38.8	41.7	48.1	2.42

[a] Standard error of difference of mean.

Table 5.16 Significant treatment effect on sensory attributes of Kishk made with wheat products (Burghol, Burghol flour or flour).

Attribute	Significance of treatment[a]		
	Source	'Dairy' base[b]	Type
Odour			
Intensity	ns	ns	ns
Creamy	*	***	ns
Acid	ns	***	ns
Fruity/sweet	ns	ns	ns
Cooked	ns	ns	ns
Cereal	ns	***	**
Cardboard	*	ns	ns
Flavour			
Intensity	ns	*	ns
Creamy	*	ns	ns
Acid	ns	***	ns
Fruity/sweet	ns	ns	ns
Cooked	ns	ns	ns
Cereal	***	***	***
Cardboard	**	ns	ns
Apple	ns	***	ns
Bitter	ns	***	ns
Salty	ns	***	ns
After-taste			
Intensity	ns	***	ns
Acid	ns	***	ns
Cereal	ns	***	*
Cardboard	*	ns	***
Mouth feel			
Viscosity	ns	ns	ns
Chalky	*	ns	***
Sticky	ns	*	***
Slimy	ns	**	***
Mouth-coating	*	ns	**

[a] Significance; ns = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.
[b] Referred to as 'milk', GDL and yoghurt.

intensity and *sticky* (flavour and mouth feel) characters were $P < 0.01$ and $P < 0.05$, respectively.

However, the treatment effect for 'dairy' x type of cereal were only significant for *cereal* (flavour) and *acid* (odour) ($P < 0.01$), *apple* (flavour) and *slimy* (mouth feel) ($P < 0.05$) (data not shown).

PCA was applied in order to visualise the main differences between the different 'particle size' of wheat product in sensory discriminant characters, and the results are shown in Figure 5.12. The variance was encompassed by the two PCs as 66.1% of which Factor 1 accounted for 35.3% and Factor 2 for 30.8%. To observe the clear differences between the variables, the biplot was split into two sub-plots. The plot of Figure 5.12A shows the Kishk groups while the plot of Figure 5.12B shows the results of sensory scores. The variance loaded on Factor 1 separated the Kishk according to the 'dairy' base used. Two main groups appeared in the biplot (Figure 5.12A). Group one associated with acidulants-based Kishks and group 2 with 'milk'-based Kishks. The former group again was segregated into two sub groups *i.e.* yoghurt- and GDL-based Kishks. However, the vector loading on Factor 2 separated the Kishk based on wheat flour *versus* Burghol and Burghol flour products, and similar product grouping were observed for 'milk'-based Kishks.

Sensory discriminant data loaded on Factor 1 showed clear separation of the different significant sensory attributes (Figure 5.12B). A cluster associated with *acid* (odour and after-taste), *cereal* (after-taste), *salty* and *bitter* (flavour) was highly significant and the effect of the treatment could be attributed to yoghurt-based Kishk. While *chalky, sticky* and *slimy* (mouth feel) dispersed near the central line, these perceived sensory attributes showed very weak treatment effect and could be associated with GDL-based Kishk. Whilst the treatment effect was significant for *cereal* (flavour) which was associated with 'milk'-based Kishk.

However, the data loaded on factor 2 also separated the sensory attributes of the Kishk with their appropriate baseline. *Chalky* (mouth feel) and *cereal* (flavour) characters which were associated with Burghol-based Kishks, but the *acid* (flavour and after-taste), *bitter*

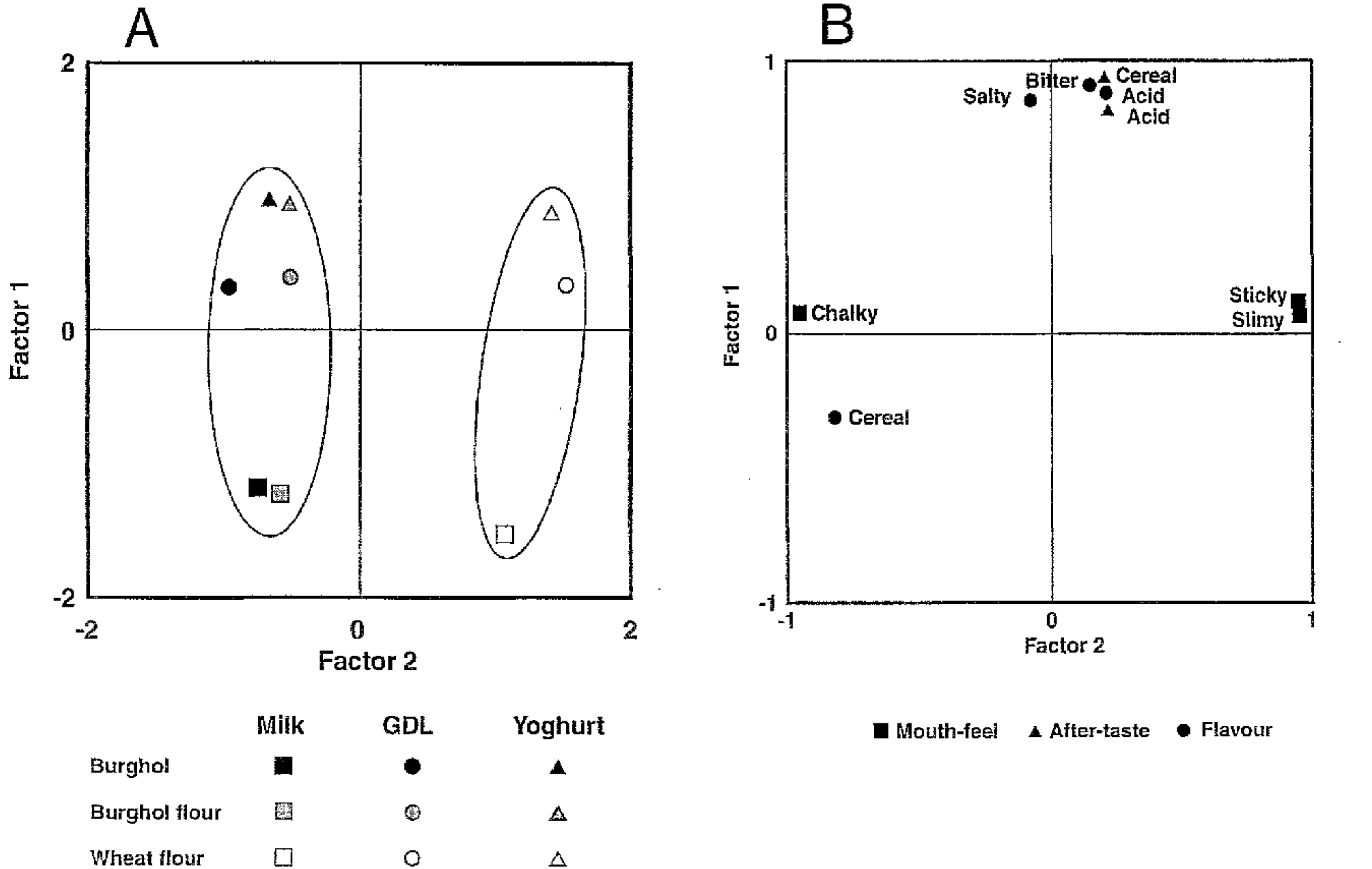


Figure 5.12 **Principal Component biplot of sensory space maps of Kishk made with different wheat products (Burghol, Burghol flour or flour).**

(flavour) and *cereal* (after-taste) characters were associated with wheat flour-based Kishk. While *salty* (flavour) is the only character which was influenced by the Burghol flour-based Kishk.

5.7 Evaluation of some aspects of the secondary fermentation during the production of Kishk

There were clear indications from the results shown in section 5.6 that 'particle size' of the wheat cereal had dominant effects on sensory space maps of the Kishk made with Burghol, Burghol flour or wheat flour (see Table 5.15). Flour, by contrast to Burghol, is a reduced whole grain particularly the starchy endosperm into smaller particle size, and particle size reduction of starch bearing matrix increases the greater accessibility to enzymatic reactions (Yiu, 1989). During the secondary fermentation stage, the enzymes present in the cereal may become active and pre-digest the macro nutrient particularly the carbohydrate and protein and to a lesser extent the fat (Asp, 1990). Consequently, production of organic acids could influence the taste, flavour and texture of the final product (El-Sadek *et al.*, 1958; Marsili *et al.*, 1981).

In order to assess the enzymatic hydrolyses of these macro nutrient, an experiment was conducted to observe the possible enzymatic effects as well as the structural changes during the secondary fermentation period. Burghol and wheat flour supplied from two different sources were only used as cereal-based products for Kishk-making, and a total of three trials were carried out using yoghurt as the 'dairy' base. In each trial and for each type of Kishk, the treatment effects are shown in Table 5.17. In the first set of four batches yoghurt was mixed with Burghol or wheat flour in order to study the role of micro-organisms including the α-amylase activity which may originate from the added cereal. However, in the second set of four experimental batches, parallel mixtures were used as described earlier plus the addition of sodium azide at a rate of 0.02 g 100 g^{-1} to inhibit the growth of micro-organisms including the starter culture. Sodium azide has a bacteriostatic effect (Bridson, 1990) and can be used as a preservative (0.1 g 100 g^{-1}) in laboratory reagents and similar products (Singleton and Sainsbury, 1978) or in antiserum (English, 1994). In this experiment, it was decided to monitor the level of soluble nitrogen in the

Table 5.17 Experimental treatments and levels.

Treatment	Levels
Base type	Yoghurt; whey from yoghurt
Cereal	Burghol; wheat flour
Inhibitor	Sodium azide
Test time	Fresh; 2, 4 and 6 days, respectively
Source	Supplier A and B

yoghurt/cereal mixtures which can provide some information regarding the bacterial activity during the secondary fermentation. Incidentally, this approach of measuring the soluble nitrogen content in the yoghurt/cereal mixture is similar, in principal, to monitor the maturity index in cheese. However, sodium azide is a hazardous chemical leading to explosion at high temperatures which makes the test for soluble nitrogen very dangerous. Thus, it was decided to run parallel samples of similar yoghurt/cereal mixtures where the sodium azide was replaced with an antimicrobial tablets (Broad Spectrum Microtab®II; D and F Control System, Inc., San Ramon, California, USA). Five tablets were added *per* 100 g of yoghurt/Burghol or wheat flour mixture for determination of soluble protein.

In the third set of this experiment, four batches of yoghurt whey/cereal mixtures were used. The whey was obtained from the natural yoghurt using a laboratory filter (Whatman no. 1) where the anticipated changes in starch structures could be examined using confocal microscopy. Also in similar parallel batches, microbial inhibitor tablet was added to visualise the microstructure in the absence of micro-organisms.

5.7.1 α-amylase activity/content

The level of α-amylase activity in the raw ingredient of Kishk (*i.e.* yoghurt and wheat products), and yoghurt/Burghol or wheat flour mixture during the secondary fermentation period was analysed, and the results are shown in Table 5.18 and Figure 5.13, respectively (see also Appendix XVI). The amount of α-amylase in yoghurt was evident (0.019 U g^{-1}), and no data are available to indicate the presence of this enzyme in yoghurt. But a highly concentrated α-amylase system was reported by Guy and Jenness (1974) which was prepared from the protein fraction precipitated from whey or concentrated milk (Ling, 1956) particularly in serum (Walstra and Jenness, 1984; Whitney, 1988), and hence such enzyme could be present in yoghurt. The average α-amylase quantity (U g^{-1}) in Burghol and wheat flour averaged 0.012 and 0.0575, respectively. A slight variation in the proximal composition between the wheat flours supplied from different sources was evident (see Table 5.18); this could be due to the factors such as growing and harvesting conditions (Towalski and Rothman, 1995) or milling. The amount of α-amylase in Burghol was lower when compared to wheat flour probably due to the parboiling stage during its preparation

Table 5.18 Proximal α-amylase (Units g^{-1}) and soluble protein (g 100 g^{-1}) of yoghurt and wheat products.

Component	α-amylase	Soluble protein
Yoghurt	0.019	0.20
Cereals		
Supplier A		
Burghol	0.012	0.56
Wheat flour	0.069	0.43
Supplier B		
Burghol	0.012	0.46
Wheat flour	0.046	0.34

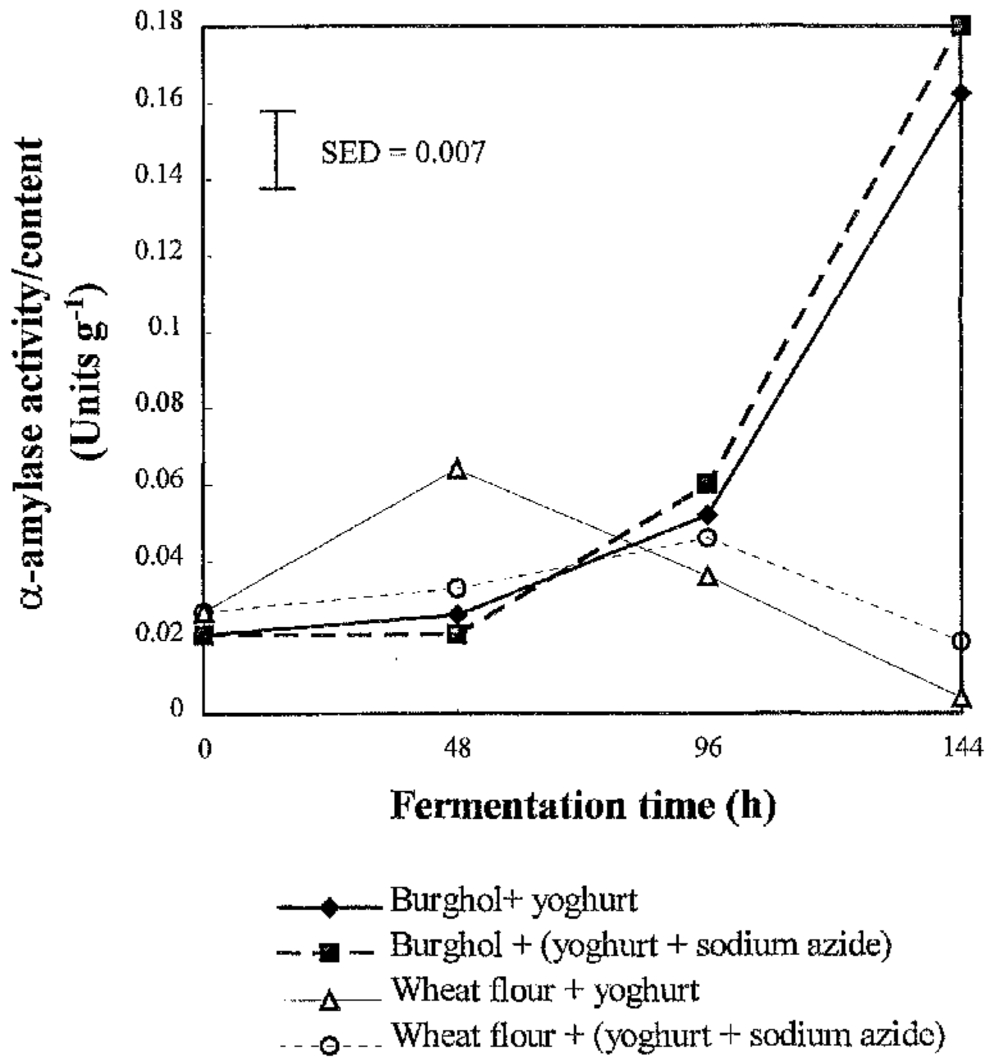


Figure 5.13 α–amylase activity/content (Units g^{-1}) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.

since high heating considerably inactivate the enzyme.

The level of α-amylase in yoghurt/Burghol or wheat flour mixtures during the secondary fermentation period provided an interesting phenomenon. For instance, the amount of α-amylase in wheat flour-based mixture was slightly higher than Burghol-based mixture up to 96 h and then decreased gradually. This was as expected because the flour contain more α-amylase than Burghol (see Table 5.18). However, in the Burghol-based mixture the α-amylase level increased sharply after 96 h until the end of the secondary fermentation period (144 h). The reason(s) is probably due to the location of α-amylase in the cellular structure of Burghol, and in the presence of adequate moisture originating from yoghurt, the starch tends to swell or possibly becomes soft rendering the release of such enzyme into the yoghurt/Burghol mixture. This enzyme remains inactive on the surface of starch granules in the starchy endosperm, but is capable of rapid action when the substrate is in solution (Kent and Evers, 1994). In case of Burghol-based mixture, the migration of aqueous phase into the grain structure could be very slow up to 48 h (see Figure 5.13), possibly due to the presence of thick wall of outermost layer of pericarp, *i.e.* outer epidermis (or outer epicarp). Afterwards the aqueous material could diffuse through the whole cellular structure of the grain, and the activity of α-amylase in different locations could develop. As a consequence, further increase of α-amylase activity appeared until the end (144 h). Thus, it is possible that the 'particle size' plays a major contributory role of α-amylase activity in carbohydrate products. A view clearly demonstrated in Figure 5.13 where wheat flour α-amylase is greater than Burghol. However, the gradual decrease of α-amylase activity in wheat flour/yoghurt mixtures at later stage of the secondary fermentation period (*i.e.* up to 144 h) may indicate that: (a) such enzyme being a proteinacious in nature and a metallo-enzyme containing calcium as a part of their molecular structure, may be denatured or inactivated with the gradual decrease in pH (Greenwood, 1970; Berk, 1976; Robinson, 1987; Salovaara, 1993), and/or (b) α-amylase is inhibited with an enzyme inhibitors such as phytic acid (Kent and Evers, 1994) present in the base ingredient of Kishk (see Table 5.4 showing phytic acid content).

The presence of sodium azide in the mixture did not reduce α-amylase level, but the level of the enzyme in yoghurt/wheat mixtures were similar to those reported above (see Figure

5.13).

Statistical analysis of α-amylase in relation to treatment effects was significant for cereal base, time, time x cereal base ($P < 0.001$), and for time x yoghurt base ($P < 0.05$). While the differences in yoghurt base, cereal base x yoghurt base, time x cereal base x yoghurt base were not significant (Table 5.19).

5.7.2 Starch content

In all the current research work acid hydrolysis method had been to measure all the acid-hydrolysis polysaccharides including those derived from the non-cellulose polysaccharides (*i.e.* pectin or hemicellulose) (Southgate, 1976). The concentration of starch in Kishk could be considered higher than expected (see Table 4.10 and 5.6). The enzymatic procedure described in section 3.10.2 is, however, more specific for measuring the starch content more accurately. In this method of analysis the starch is hydrolysed by α-amylase and totally solubilised followed by hydrolysis of the starch dextrins to glucose by amyloglucosidase. Thus, the starch content of the yoghurt/Burghol or wheat flour mixture during the secondary fermentation period was determined using the enzymatic method, and the results are shown in Figure 5.14. All the results of the different batches of yoghurt/Burghol or wheat flour mixtures are shown in Appendix XVI. Starch content of wheat flour-based yoghurt mixture was higher compared to Burghol-based mixture at the beginning of the secondary fermentation period (0 h). This was as expected because the wheat flour contained higher level of starch compared to Burghol (see Table 5.2). Afterwards the starch content decreased gradually up to the 144 h where the level of starch was reduced by ~ 50%. Also when sodium azide was used in the yoghurt/Burghol or wheat flour mixture the reduction in the starch content was also reduced in a similar pattern, *i.e.* relatively linear. The results shown in Figure 5.14 indicate a much lower starch content in the final product compared to Kishk (see Tables 4.10, 5.6), possibly because the starch granules physically changed into a resistant form (Gruchala and Pamernaz, 1992) during the secondary fermentation period. Furthermore, this enzymatic test method has been developed to measure starch in dried milled products such as flour, and the 'particle size' is important. Other possible factors, which may have affected the enzymatic reaction(s),

Table 5.19 Significant treatment effect in α-amylase, total starch content and soluble protein of yoghurt and wheat cereal component mixture during the secondary fermentation period.

Factors	Treatment effect[a]		
	α-amylase	Total starch	Soluble protein
Cereal base	**	ns	***
Liquid base	ns	ns	ns
Cereal base x liquid base	ns	ns	ns
Time	***	***	***
Time x cereal base	***	**	***
Time x liquid base	*	*	*
Time x cereal base x liquid base	ns	ns	***

[a] Significance; ns = not significant, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

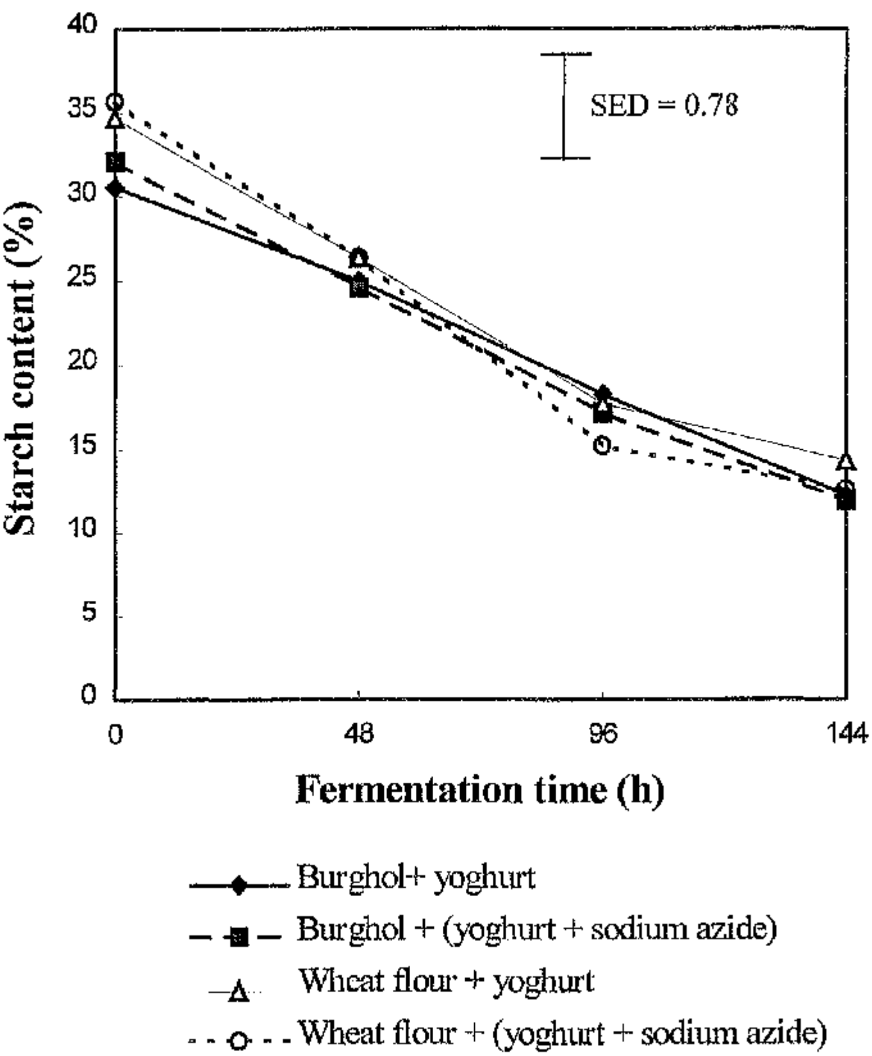


Figure 5.14 Starch content (g 100 g^{-1} DMB) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.

could include the following:

- Although the extent of starch hydrolysis was similar in the Burghol and flour (see Figure 5.14), this does not reflect the enzymatic activity of α-amylase (Figure 5.13); however, the differences in the enzyme activity was relatively small which did not have any significant effect on the starch hydrolysis. Furthermore, the α-amylase activity is not the only limiting factors for the starch hydrolysis, other factors, which should be considered are: (a) the 'particle size' difference between the Burghol and wheat flour, (b) the embeddment of starch within the protein matrix (see Figure 5.19), and (c) the assay test indicating greater enzymatic activity than what is actually taking place in the yoghurt cereal mixture.
- In the enzymatic test, dried milled samples are used, and in this experiment the test was performed on wet samples (McCleary, personal communication). In order to quantify the enzymatic method, 2 samples of Burghol-based Kishks were used to determine the starch content and the results (42.16 g 100 g^{-1}) were similar to the Polarimetric method. Therefore, the data shown in Figure 5.14 shows qualitatively the starch content in the sample rather than quantitatively.
- Starch molecule can be depolymerized by either α-amylase or acids (BeMiller and Whistler, 1996), but the low pH originating from yoghurt may suppress some of the α-amylase activity and other enzymes (Salovaara, 1993). While mild acid is not effective to hydrolyse the starch granules completely (Camargo *et al.*, 1988).
- The optimum activity of α-amylase ranges between 5 and 8.5 pH (Greenwood, 1970; Robinson, 1987). The decrease in pH causes the inactivation of amylases (Böcker *et al.*, 1995) because these appear to be metallo-enzymes, containing calcium as part of their molecular structure (Greenwood, 1970; Berk, 1976; Robinson, 1987) and being a protein in nature may denature. Consequently, α-amylase is inactivated in acidic foods and frequently exists as different isoenzymes (Robinson, 1987).
- When starch granules are immersed in water, moisture is readily takes up and if a dilute starch solution stands for long period of time, linear molecules slowly line up and 'zip' together in parallel bundles resulting in particles too large to remain in solution. The relatively long amylose molecules that escape from swollen granules into the continuous phase and become insoluble, aggregate or crystallise, and

consequently, become resistant to enzymatic hydrolyses (Pomernaz, 1991).

- Interactions can take place between starch and other components like lipids (Larsson and Miezis, 1979; Holm *et al.*, 1983), proteins (Anderson *et al.*, 1981; Jenkins *et al.*, 1987), polyphenols (Thompson *et al.*, 1984; Bjorck and Nyman, 1987) or phytic acid (Yoon *et al.*, 1983; Thompson, 1986), forming complex interactions which can resist enzymatic hydrolysis.

Analysis of variance showed that significant differences for time ($P < 0.001$), time x cereal base ($P < 0.01$) and time x yoghurt base ($P < 0.05$). While the treatment effect for cereal base, yoghurt base and time x cereal base x yoghurt base was not significant (see Table 5.19).

5.7.3 Soluble protein content

Non-protein nitrogen (NPN) compounds (*i.e.* urea-N, creatine-N, creatinine-N, uric acid-N, orotic acid-N, hippuric acid-N, peptide-N, ammonia-N, α-amino acids-N) are present in milk and their increase in the product reflect the metabolic activity of micro-organisms of the protein. For example, the soluble protein content of cheese during storage is indication of the maturation index of the product (Walstra and Jenness, 1984); Jenness, 1988). The level of such compounds in the raw ingredient of Kishk (*i.e.* yoghurt, Burghol and wheat flour), and yoghurt/cereals mixture during the secondary fermentation period was analysed, and the results are shown in Table 5.18 and Figure 5.15, respectively. Appendix XVI shows the individual results of the experiment. The average content (g 100 g^{-1}) of NPN in yoghurt, Burghol and wheat flour averaged 0.20, 0.51 and 0.39, respectively. A slight variation in NPN content between the cereals supplied from different sources was evident (see Table 5.18), and the reason(s) could be due to growing and harvesting conditions (see section 5.7.1).

The NPN content during the secondary fermentation was higher in wheat flour-based mixture compared to Burghol-based mixture (see Figure 5.15). No increase in NPN content was evident in Burghol-based mixture up to six days, whilst in flour-based mixture a sharp increase was obtained. The reason(s) could be attributed to the availability of

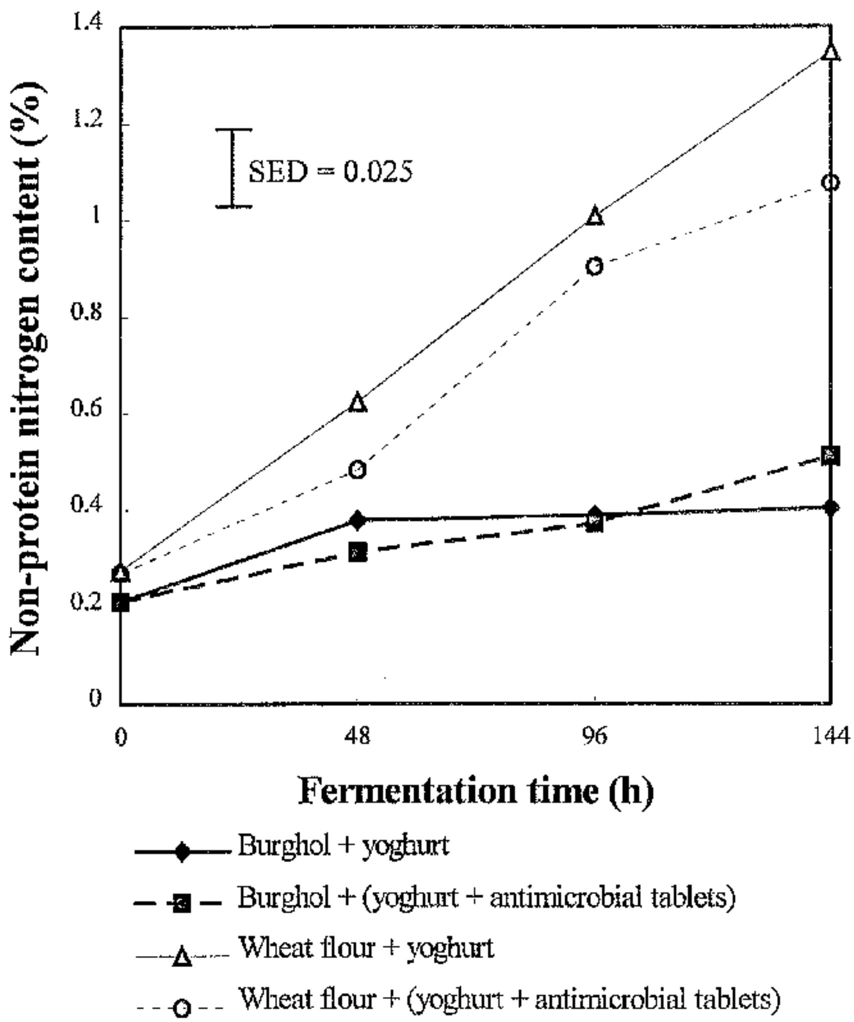


Figure 5.15 Soluble protein content (g 100 g^{-1}) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.

protein for hydrolysis in the flour and more protective by the starch cellular structure of Burghol. Also, the particle size of the cereal may have played a contributory role affecting the rate of proteolytic activity. However, the addition of the antimicrobial tablets to the mixture in order to control the microbial activity had a similar effect on the amount of NPN in Burghol- or wheat flour-bases.

Analysis of variance showed significant differences for the cereal base, time, time x cereal base, time x cereal base x yoghurt base ($P < 0.001$) and time x yoghurt base ($P < 0.05$). While treatment effect was not significant for yoghurt base and cereal x yoghurt base (see Table 5.19).

5.7.4 Microbiological quality

5.7.4.1 Microbiological analysis

Since the Burghol or wheat flour used in this experiment were as those described in section 5.2, the microbiological quality could be assumed the same (see Table 5.4). However, total colony count (non-lactic acid bacteria) in yoghurt was recovered 1.2×10^3 cfu g^{-1}, while no coliforms or yeasts and moulds were evident at 10^{-1} dilution.

Microbiological quality of yoghurt/Burghol or wheat flour mixtures during the secondary fermentation was analysed, and mean results are shown in Table 5.20, and Appendix XVII details the individual results. Total colony count (cfu g^{-1}) of non-lactic acid bacteria in Burghol- and wheat flour-based mixtures at the beginning of the fermentation (0 h) were 8.5×10^3 and 1.8×10^4, respectively. These organisms may have originated from the cereals (see Table 5.4) and possibly the yoghurt. After six days the count increased to 1.3×10^9 and 9.3×10^8 cfu g^{-1}, respectively. However, the addition of sodium azide controlled the growth of non-lactic acid bacteria during the fermentation period, and the counts only increased from 6.4×10^2 to 5.2×10^3 cfu g^{-1} in Burghol-based mixture, and from 5.1×10^2 to 2.4×10^3 cfu g^{-1} in wheat-based product. It is evident that sodium azide has a bacteriostatic effect against most of the Gram-negative bacteria, but permits the growth of Gram-positive bacteria (Bridson, 1990).

Table 5.20 Microbial count (cfu g^{-1}) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.

Kishk sample	Total colony count				Coliforms				Yeasts and moulds			
	0 h	48 h	96 h	144 h	0 h	48 h	96 h	144 h	0 h	48 h	96 h	144 h
Burghol	8.5×10^3	4.4×10^4	2.0×10^7	1.3×10^9	<10[a]	<10	<10	<10	<10	1.4×10^2	1.5×10^4	2.5×10^5
Burghol + sodium azide	6.4×10^2	9.0×10^2	5.2×10^3	3.7×10^3	<10	<10	<10	<10	<10	<10	<10	<10
Wheat flour	1.8×10^4	8.7×10^4	6.0×10^7	9.3×10^8	<10	<10	<10	<10	<100	3.3×10^2	2.0×10^4	2.4×10^5
Wheat flour + sodium azide	5.1×10^2	4.0×10^2	2.4×10^3	2.4×10^3	<10	<10	<10	<10	<10	<10	<10	<10

[a] No growth at 10^{-1} dilution.

Results are average of single sample plated in duplicate of yoghurt/Burghol or wheat flour mixture (supplied from two sources).

No growth of coliforms at 10^{-1} dilution was evident in yoghurt/Burghol or wheat flour mixtures during the secondary fermentation period. However, yeasts and moulds were only recovered from yoghurt/cereal mixtures without the addition of sodium azide, whilst in other mixtures the counts have increased by three $\log_{10}$ cycles (see Table 5.20). As expected the yeasts and moulds can grow in acidic conditions, and most likely that the cereals could be the source of contamination (see Table 5.4).

5.7.4.2 Enumeration of starter organisms

The starter organisms (*i.e. Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus*) originating from the yoghurt were recovered at high counts $>10^8$ cfu g^{-1} (see Table 5.21), and Appendix XVIII shows the individual results of the experiment. *Str. thermophilus* and *Lb. debrueckii* subsp. *bulgaricus* counts (cfu g^{-1}) during the fermentation period have increased by 2 $\log_{10}$ cycles, and these organisms did not survive in the presence of sodium azide. Similar counts of these organisms were reported by Damir *et al.* (1992) during the fermentation of skimmed milk Kishk up to the 96 h fermentation, but in later stage they observed a decrease in counts.

5.7.5 Microscopic analysis

Microscopy is a useful technique to visualise the microstructure of raw materials and final products which are important particularly in new products development. Such scientific technique has played a vital role, in part, to understand food behaviour (Lewis, 1986). For example, it is used to show the spatial distribution of components and overall structure of the ingredients and finished products. Microscopy has been used successfully to study dairy and food products for many years, and Kalab (1993) has reviewed the importance of microscopy in dairy research. Various techniques of microscopy are available, for example, light microscopy using different optical techniques such as brightfield, phasecontrast, darkfield, fluorescence and confocal laser scanning. One advantage of light microscopy is the ability to distinguish components such as protein, fat and bacteria by specific staining, and it is also convenient and rapid (Kalab, 1995). However, in brightfield microscopy, the images of particles observed using ordinary light may give insufficient

Table 5.21 Enumeration of starter organisms (cfu g^{-1}) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.

Kishk sample	*Str. thermophilus*				*Lb. delbrueckii* subsp. *bulgaricus*			
	0 h	48 h	96 h	144 h	0 h	48 h	96 h	144 h
Burghol	8.5×10^{9}	2.2×10^{10}	3.9×10^{11}	3.5×10^{11}	1.3×10^{8}	5.8×10^{8}	6.6×10^{10}	6.1×10^{10}
Burghol + sodium azide	<10[a]	<10	<10	<10	<10	<10	<10	<10
Wheat flour	2.6×10^{10}	1.4×10^{11}	1.2×10^{12}	1.8×10^{13}	3.1×10^{8}	1.4×10^{9}	1.3×10^{11}	6.3×10^{11}
Wheat flour + sodium azide	<10	<10	<10	<10	<10	<10	<10	<10

[a] No growth at 10^{-1} dilution.

Results are average of single sample plated in duplicate of yoghurt/Burghol or wheat flour mixture (supplied from two sources).

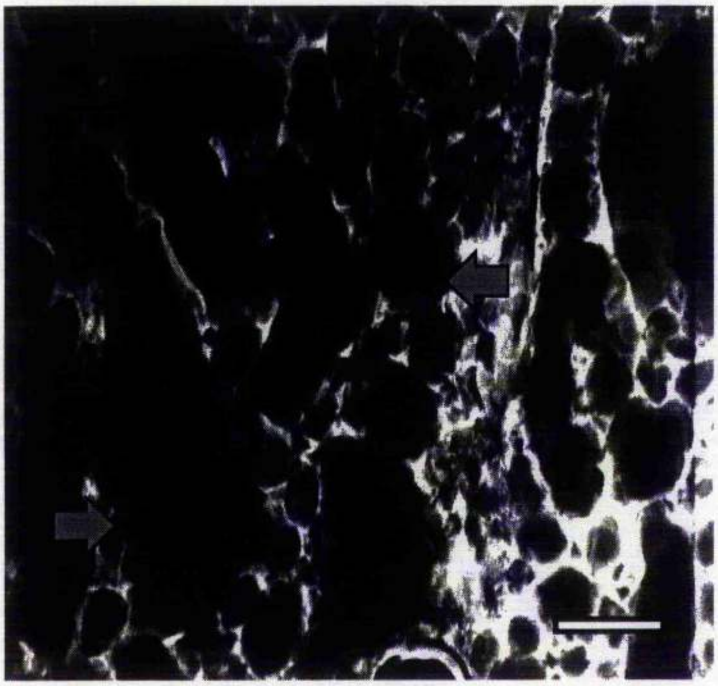
resolution to visualise the smaller particles. Phasecontrast microscopy is used to observe transparent objects that would be nearly invisible to the conventional microscope. Its effect is to enhance the phase differences between light rays going through the object and the surrounding medium. In darkfield microscopy, the image of the sample is presented on a dark background so that small details in colourless sample appears to have greater contrast and their natural colour is enhanced. Fluorescence microscopy relies on fluorescent dyes uptake by viable microbial cells, and this technique measures the behaviour of these cells. All forms of conventional microscopy suffer from blurring of images from out of focus regions in thick samples. The confocal laser scanning microscopy (CLSM) is a recent development which improves the resolution of the light microscopy (Blonk and van Aalst, 1993). Monochromatic laser light is used to illuminate the sample, and images are measured in the form of electronic signal which allows a range of electronic image-processing techniques (Sheppard, 1993). By using small (confocal) aperture in the illumination system it is possible to minimise blurring effect. This in turn leads to the ability to construct 3-D images by computer reconstruction of optical sections.

Electron microscopy has become almost a routine analytical technique in dairy research to observe the particle sizes and structures using a focused electron beam instead of light (Kalab, 1993). Electro-magnetic lenses are used instead of glass optics because it can examine structures much smaller than the limit of resolution for light microscopy. Two types of electron microscopy can be used: (a) scanning electron microscopy (SEM) which allows scanning of the sample, and (b) transmission electron microscopy (TEM) which offers higher resolutions, and usually require special sample preparation. However, these techniques could not be used in the present study due to lack of facilities, and hence, Kishk was examined using CLSM to study the homogeneity of yoghurt/cereals mixture during the secondary fermentation period.

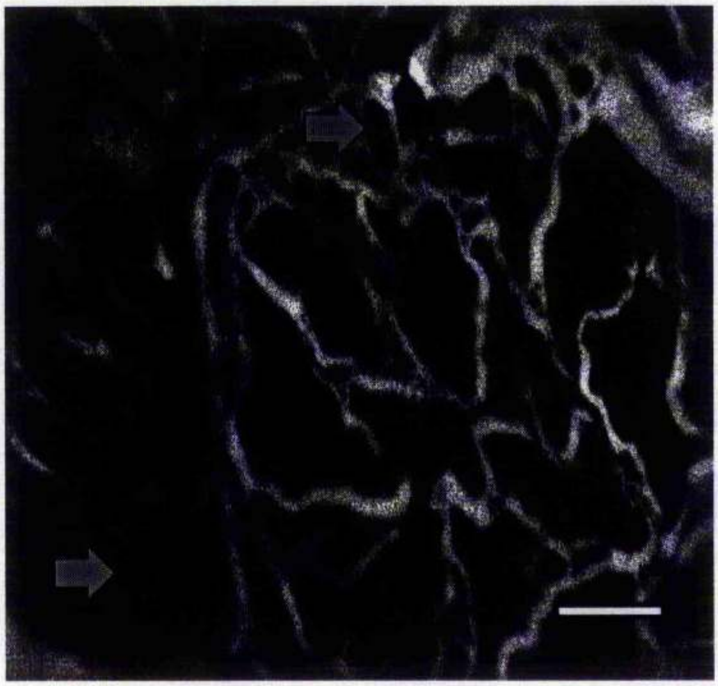
In fact, the inhomogeneity of the mixture due to the different phases used [*i.e.* dried (Burghol) and liquid (yoghurt)] to prepare the Kishk, it was difficult to illustrate the particle images of both phases in the similar zoom factor. Thus, different approaches were applied to adjust the zoom factor to change the area of the mixture that may be easier to view. For example, setting a lower zoom factor has the advantage to increase the field of view which provides smaller images, whilst setting higher zoom factor decrease the field of view but provides larger images (Centonze and Pawley, 1995). Using such approaches to the yoghurt/Burghol mixture, the zoom factor was adjusted at 3.5 to visualise a wider field depth. Images taken at such zoom factor showed that the starch granules were dominant in the mixture(s) due to their larger particle size, and higher content compared to others (see Tables 5.5 and 5.6). Figure 5.16A illustrates the starchy endosperm of yoghurt/Burghol mixture when fresh. The starch consisted of a population of granules of variable shape (see Figure 5.16 - arrows), but generally have smooth surface curves, and some of the granules are essentially oval in shape and deformed. These starchy images were possibly influenced by the manufacturing stages of Burghol where the grains were steeped in boiling water, dried to its original moisture content, rehydrated with ~ 20% moisture, cracked and dried (Tamime and O'Connor, 1995). Similar microstructural changes in wheat starch dispersions during heating and cooling have been reported by Langton and Hermansson (1989), and the microstructure of starch granules at the end of fermentation period (144 h) were irregular in shaped, swollen and tend to stick together (see Figure 5.16B - arrows). Even when sodium azide was added to the mixture to control the microbial activity, no difference(s) was observed in the behaviour of the starch granules (see Appendix XIXA).

The second approach of CLSM applied, however, was to visualise the yoghurt area or phase of the mixture (yoghurt and Burghol) in more detail. Since no change was expected at freshly mixed samples, the images at 48 h and 144 h were selected for comparison purposes. Figure 5.17A illustrates the image of yoghurt/Burghol mixture at 48 h of the secondary fermentation period, and this shows a relatively even distribution of casein aggregates throughout the gel matrix. After 144 h, however, the casein aggregates have become more irregularly spaced (Figure 5.17B). This is likely due to loss of moisture from the yoghurt and parallels the swelling in the starch. Such denser microstructure was similar to strained yoghurt (Labneh; 22 - 26 g 100 g^{-1} total solids) reported by Kalab (1993). The protein matrix was evenly distributed and consisted of aggregates of casein micellar chains and clusters (see Figure 5.17A - small arrow). However, the small starch granules were also evenly distributed in the microstructure (see Figure 5.17A - large arrow), and at the end of the secondary fermentation period (144 h) greater aggregation of casein micelles

A



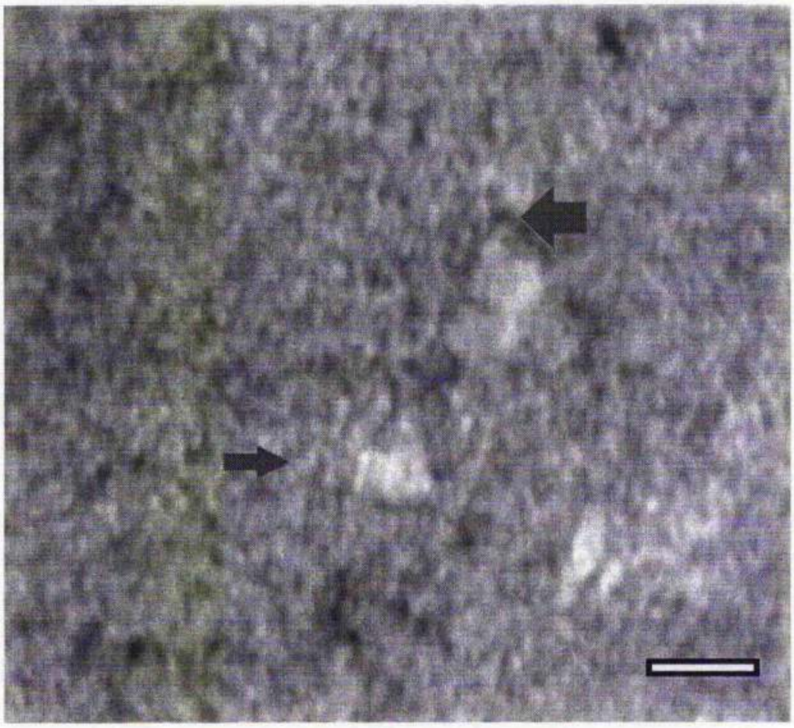
B



Arrows showing starch granules.

Figure 5.16 Starchy endosperm of yoghurt/Burghol mixture during the secondary fermentation period; 0 h (A), 144 h (B). Bar size = 10 μm.

A



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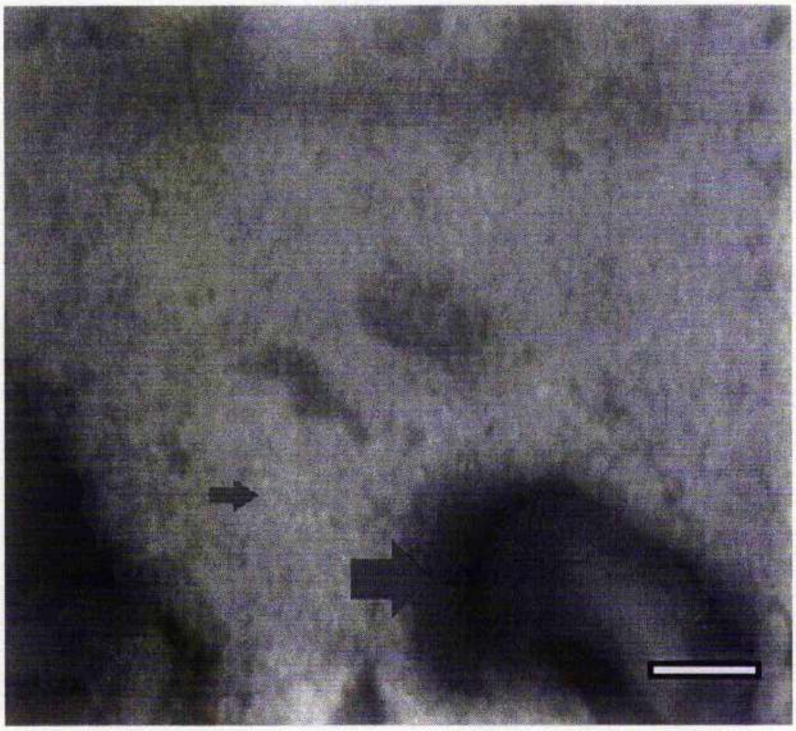


Arrows (large) showing starch granules and (small) casein aggregates.

Figure 5.17 Microstructure of yoghurt/Burghol mixture using zoom factor 10; 48 h (A), 144 h (B). Bar size = 5 μm.

became evident due to more acid produced by micro-organisms and the swelling of the starch granules [see Figure 5.17B - arrows (small and large, respectively)].

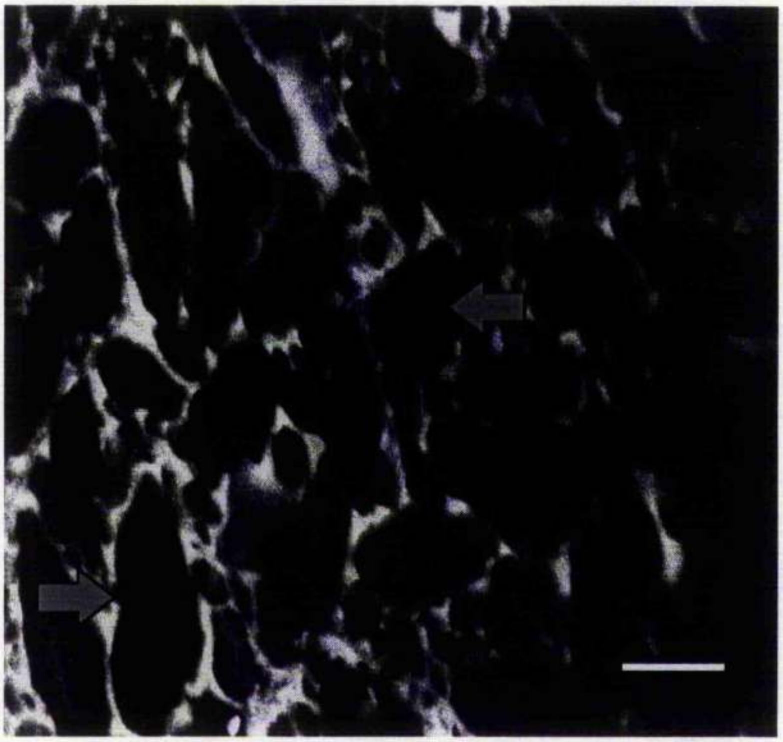
Furthermore, when Burghol was mixed with whey obtained from yoghurt in order to visualise the hydrolysis of starch in acidic medium, no significant differences were observed in the microstructure of starch granules when freshly mixed and at the end of the fermentation period (see Figure 5.18A and B - arrows). Also, the addition of antimicrobial tablets to the mixture to control the microbial activity showed relatively similar pattern of the structure of the starch (see Appendix XIXB).

Figure 5.19A illustrates the image of yoghurt/wheat flour mixture at 0 h of the secondary fermentation period, and it can be observed that the starch granules were evenly distributed in the mixture. The majority of them were smaller in size compared with the Burghol/yoghurt mixture (see Figure 5.16). On some occasions, some of starch granules appeared larger in size, irregular in shape, and tended to stick together for no apparent reason (see Figure 5.19A - large arrow). However, since the majority of starch granules were small, the composition of the wheat flour may have influence the size because it contained reduced starchy endosperm. The casein micelles originating from yoghurt were also evident, and evenly distributed in parallel to the starch granules which consisted of micellular aggregates or chains (see Figure 5.19A - small arrow). At the end of the secondary fermentation period (144 h), the starch granules were variable in shape and size, [*i.e.* small (spherical) or large (lenticular and/or oval)], swollen and irregular (see Figure 5.19B - large arrow). When sodium azide was added to the mixture, the microstructure was similar to that shown in Figure 5.19B, but the starch granules were more swollen, tended to stick together, and the protein matrix was more compact which might be due to the higher titrable acidity in the mixture [(see Appendix XIXC - arrows (large and small, respectively)].

5.8 Conclusions

Different cereal products, acidulants and 'milk' were used to study the influence of the cereal type, 'particle size' and/or 'dairy' base on the quality of Kishk. 'Milk'-based Kishk

A



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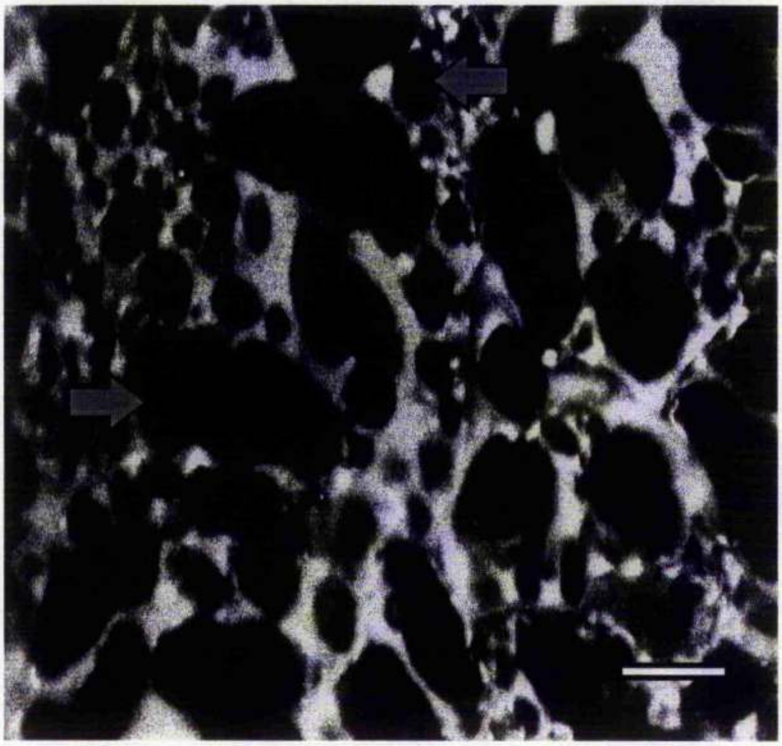
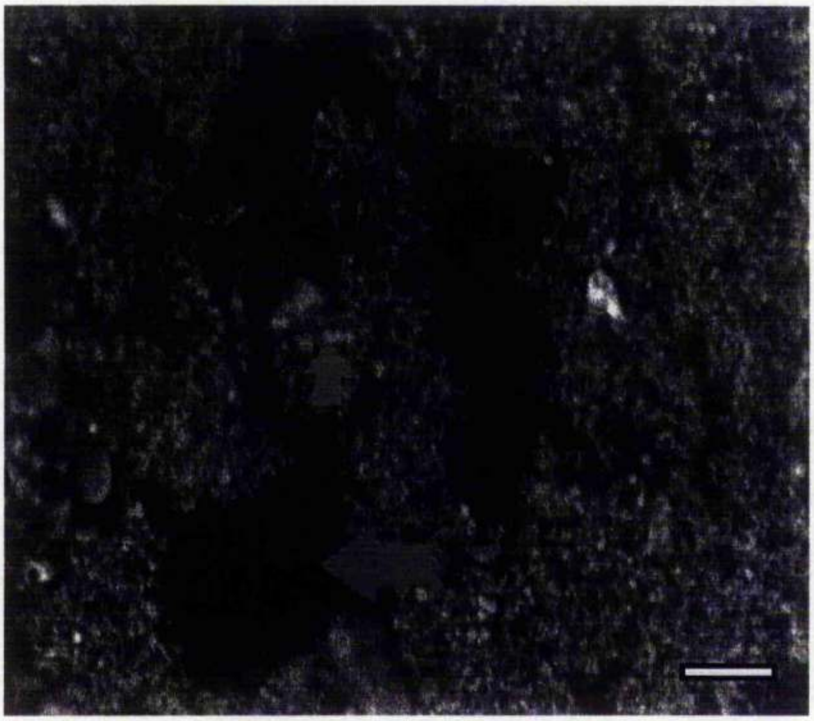


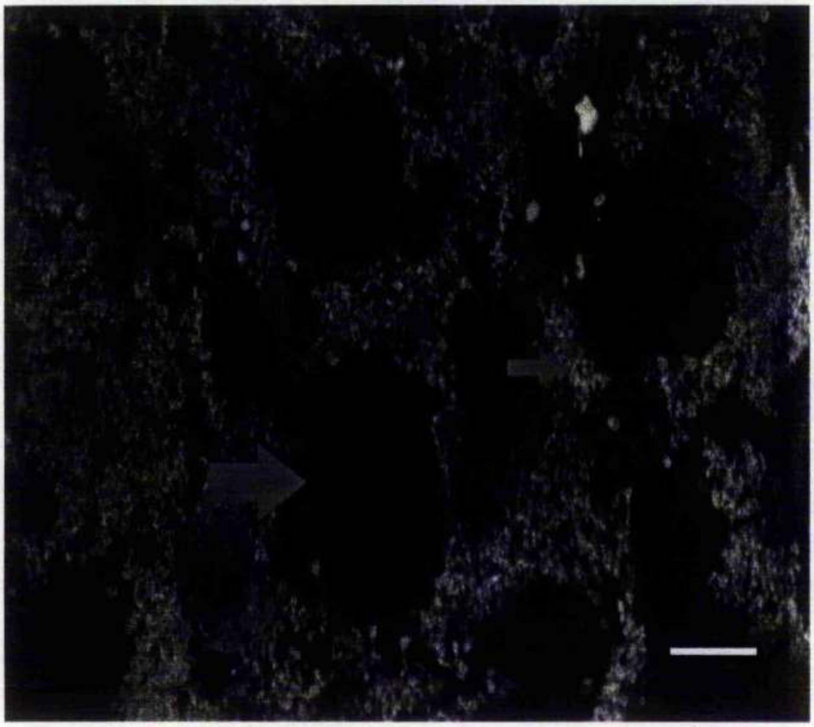
Arrows showing starch granules.

Figure 5.18 Starchy endosperm of whey/Burghol mixture during the secondary fermentation period; 0 h (A), 144 h (B). Bar size = 10 μm.

A



B



Arrows (large) showing starch granules and (small) casein aggregates.

Figure 5.19 Microstructure of yoghurt/wheat flour mixture during the secondary fermentation period; 0 h (A), 144 h (B). Bar size = 10 μm.

was produced in order to compare it with a 'similar' product known as Scottish porridge/gruel. Salt in such Kishk was not added because the mixture was not subjected to the secondary fermentation period, to control the acid produced by starter organisms and/or to mask or partially neutralise the acid taste of the product. The efficacy of the role of the starter organisms on the flavour of the product was observed by using GDL compared *per se* with yoghurt. Direct acidified milk was similar to that of a typical yoghurt-based product, and was successfully produced using GDL (2 g 100 g^{-1}) at 45 ±1°C.

Variation in the gross composition of the cereals (porridge oats, oats flour, Burghol and wheat flour), carbohydrate-based and mineral contents of the cereals used was evident. The biplot of Principal Component Analysis using correlation matrix separated the cereals according to their type. Nevertheless, the variations were also evident in the Kishks. The type and 'particle size' of cereals, and 'dairy' base affected the quality of the Kishk. Fat and starch contents of GDL-based Kishk were lower compared to other Kishks because the rate of pH drop was faster compared with microbial fermentation, and as a consequence, these components were embedded in the coarser gel matrix; such complicated structure may have interfered with complete extraction of fat or starch components from the dried products. These results might also indicate the possible interaction during the secondary fermentation period, and merits further exploration to improve the analytical technique. PCA was used on the correlation matrix of the data, and identified and mapped out the Kishks in relation to the 'dairy' bases and type of cereal used.

Differences in the profile of organic acids content in the Kishks were evident. The yoghurt-based Kishks had higher levels of lactic acid content compared to Kishk made with GDL or 'milk'. Propionic acid was evident in all the different 'dairy'-based Kishks due to presence of propionic acid bacteria that might have originated from the cereals. The level of acetic and propionic acids in GDL-based Kishk were much higher compared to the other products.

Microbiological quality of all the Kishk was within an acceptable range. In all the products (fresh and stored) coliforms, yeasts and moulds [with exception of oats-based Kishk (fresh)] were < 10 cfu g^{-1}. In general, the low microbial counts of the product may suggest that the production of Kishk carried out under good sanitary conditions and hygiene standards.

Appreciable colony counts of yoghurt organisms (*i.e. Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus*) were found in fresh Kishk. The viability of these organisms after storage period (6 and 12 month) in wheat-based Kishks could be assumed as safeguard of the product, but in the oats-based products these organisms tended to die out after about 6 months storage.

The sensory properties of Kishk were influenced by 'dairy' base and type of cereals including the 'particle size'. Notable differences were observed in most of the characters of odour, flavour, after-taste and mouth feel. The mouth feel characters (*chalky, sticky, slimy*) differentiated the Kishk according to the cereal type used, and sensory space maps including star plot separated the Kishks according to these perceived mouth feel characters especially the wheat-based products.

Different wheat cereal products were used to confirm the effect of 'particle size' of the cereals on the sensory properties of the Kishk. The perceived mouth feel characters of wheat flour-based Kishk was different from Burghol- or Burghol flour-based Kishk. The treatment effect was highly significant interms *acid* (flavour and after-taste), *cereal* (after-taste) and *bitter* (flavour), and associated with wheat flour-based Kishks. Burghol-based Kishk perceived *chalky* (mouth feel) and *cereal* (flavour) characters, but the Burghol flour-based Kishk was only influenced by *salty* (flavour) character. In addition, sensory space maps clearly separated the Kishk according to the particle size.

The effect of α-amylase on macro nutrients of yoghurt/Burghol or wheat flour mixture of Kishk was studied during the secondary fermentation period, and sodium azide and antimicrobial tablets were used to control the microbial growth in the mixture. The gradual linear decrease in starch content of the mixture (Burghol- or wheat flour-based) up to the end of fermentation period (144 h) was evident, but no significant difference between both mixtures was found. The addition of sodium azide in the mixture did not show considerable increase or decrease in the starch content of the appropriate mixtures. These observations were not in agreement to the level of α-amylase observed which was high in Burghol-based and low in wheat flour-based mixture. In addition, starch content at the end of the secondary fermentation period was much lower compared to Kishk (*i.e.* after drying) which could be influenced by the analytical technique used. Such enzymatic method was developed for dried powders, and when applied for wet products containing large cereal particle (*e.g.* Burghol), quantitative determination of the starch content was not accurate. To quantify the artefact in the method, it was applied for dried powder of Kishk, and the results obtained were similar to that of polarimetric method. Therefore, the efficacy of such method of analysis merits further investigation if it used in Kishk during the secondary fermentation period

The microstructure of yoghurt/Burghol or wheat flour mixture suggested that there was a physical change in starch granules rather than degradation. No difference was observed when sodium azide was mixed to the mixture. In addition, no significant differences were also observed in the microstructure of the starch granules when whey from yoghurt was mixed with the Burghol.

CHAPTER SIX:

GENERAL DISCUSSION AND CONCLUSION

CHAPTER 6: GENERAL DISCUSSION AND CONCLUSIONS

The chemical composition of laboratory-made Kishk were within the range of commercial samples of Lebanese Kishks (Tamime and O'Connor, 1995). This suggests that the ratio of yoghurt/cereal mixture (4:1) used for Kishk-making throughout the present study was appropriate.

Production of Burghol from different cereals (oats and/or barley varieties) offered new possibilities for the use of different types of cereals for Kishk-making. However, some difficulties, particularly in oats, were experienced during the production of Burghol which was due to its closely adhered grain structure with the husk. Possible suggestions may include the modification of the process of cracking or the use of naked or de-hulled oats or barley would facilitate the production of cracked products from the cereals. In all the parboiled products (Burghols) made from different varieties of barley, oats or wheat , the majority of nutrients recovered were lower than the original grains. These loss may be controlled by adjusting the processing conditions.

Variation in the proximate composition, carbohydrate-based content, fatty acids and mineral contents of Kishk made with different cereal Burghols was observed because of the type of cereal Burghol used. Oats Burghol-based Kishk could be a good dietary source of β-glucan, fibre, mono-unsaturated and certain minerals, however, wheat Burghol is a good source of iron (i.e. ~ 21 mg 100 g^{-1} in Kishk) which is deficient in dairy products.

Microbiological quality of Kishk made with different cereal Burghols was good. The growth of some micro-organisms in the product (*i.e.* non lactic acid bacteria) may have originated from Burghol. But the low microbial counts (< 10 cfu g^{-1}) of coliforms, yeasts and moulds in the product suggest that the production of laboratory-scale Kishk was produced under good sanitary conditions and hygiene standards, and these microbial level may be not of significant count bacteriological.

Sensory properties of Kishk made with different cereal Burghols were influenced by the type of Burghol (*i.e.* oats, barley or wheat), and clearly differentiated by sensory space maps according to the type of cereal used. The perceived sensory attributes such as aroma (*cooked* and *cereal*), flavour (*acid* and *apple*), and mouth feel and texture (*viscous*, *grainy* and *sticky*) characters differentiated the Kishk from porridge oats.

Variation in the proximate composition, carbohydrate-based content and mineral contents of Kishk made with different cereals, acidulants and 'milk' was also observed, and the results may suggest the influence of type and 'particle size' of cereal, and 'dairy' base used on the product. The low level of some nutrients (*i.e.* fat, ash and starch) in GDL-based Kishk compared to other Kishks made from same cereal source was evident. It is possible to suggest that the low fat content in GDL-based Kishk could be due to the entrapment of fat globules in the protein matrix resulting in the formation of a complexed structure which interfered with the complete extraction of fat component from the product. Also, the low ash and starch contents may indicate possible interactions between different components during the secondary fermentation. These aspects would require further examination in order to explain the mechanisms to eliminate any artefacts in the analytical techniques.

The organic acids profile of Kishk made with different cereals, acidulants and 'milk' was different. Yoghurt-based Kishk contained higher content of lactic acid compared to other Kishks ('milk'- or GDL-based) made from same cereal source which was due to the metabolic activity of yoghurt organisms (*Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus*). While GDL-based Kishk showed the higher content of propionic and acetic acids, and may suggest the metabolic activity of residual bacteria originating from the cereals used.

Microbiological quality of Kishk made with different cereals, acidulants and 'milk' observed was within the acceptable range. The non-lactic acid bacteria in yoghurt-based Kishk after 12 months storage showed decrease in viable counts, and may suggest the inhibitory effect of organic acids produced by *Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus*. In all the Kishks (fresh and stored), the coliforms, yeasts and moulds counts were low (<10 cfu g^{-1}) [with exception of oats-based Kishk (fresh)], and these results suggest the hygienic standards of the products.

The enumeration of yoghurt organisms (*Str. thermophilus* and *Lb. delbrueckii* subsp. *bulgaricus*) showed an appreciable viable counts (~ $8x10^5$ and 2.2x 10^5 cfu g^{-1}, respectively) in all the fresh Kishks made with different cereals and yoghurt. The viability of these organisms after storage period (6 and 12 months) in wheat-based Kishks may suggest the safeguard of the product. However, in oats-based Kishks, for no apparent reason(s) the viability of these organisms was inhibited after 6 months storage period

Notable differences were observed in the sensory properties of Kishk made with different cereals (porridge oats, oats flour, Burghol and wheat flour) and 'dairy' base, and most of the characters of odour, flavour, after-taste and mouth feel may suggest the influence of 'dairy' base used. But the mouth feel characters (*i.e. chalky, sticky, slimy*) of the Kishks have been influenced by the type and particle size of the cereals used.

The sensory properties of Kishk made with different wheat products (Burghol, Burghol flour and flour) were different, and influenced by the type of wheat product used. Wheat flour-based Kishk perceived higher score for mouth feel characters followed by Burghol flour-based and Burghol-based Kishk. However, the perceived mouth feel characters (*chalky, sticky, slimy* and *mouth-coating*), and the sensory space maps of these Kishks suggested the influence of the 'particle size' of the wheat product used.

The effect of the 'particle size' of wheat products (Burghol and wheat flour) during the secondary fermentation period showed that the α-amylase activity/content appeared higher in Burghol-based mixture and lower in wheat flour-based mixture at the end of the secondary fermentation period (144 h). However, the opposite trend was observed where the non-protein nitrogen content was higher in the latter mixture. These results suggest that for α-amylase and proteolytic activities of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period were influenced by the 'particle size' of the cereals. The trend of gradual decrease in the starch content was similar in both mixtures (Burghol- and wheat flour-based) during the secondary fermentation period (144 h). The addition of sodium azide did not show an appreciable increase or decrease in the starch content of the appropriate mixtures. The pattern of decrease in the starch content was not in agreement with α-amylase activity observed which was high in Burghol-based and low in wheat flour-based mixtures. In addition, starch content observed at the end of the secondary fermentation period was much lower compared to Kishk (dried product) which could be influenced by the analytical technique used. The enzymatic method was developed for dried powders, and when applied for wet products containing large cereal particles (*e.g.* Burghol), quantitative determination of the starch content was not accurate. Therefore, the efficacy of such method of analysis merits further investigation if it used in Kishk during the secondary fermentation period.

The microstructure of yoghurt/Burghol or wheat flour mixture using confocal laser scanning microscopy suggested that physical change(s) in the starch granules occurred rather than degradation during the secondary fermentation period.

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APPENDICES

Appendix I Chemical composition ($g\ 100g^{-1}$)[a] of Kishk made with different cereal Burghols.

Kishk samples	Moisture	Protein	Carbohydrate	Fat	Ash	Salt
Trial 1st						
Oats						
Adamo	10.87	20.23	61.60	10.87	7.30	3.92
Dula	10.18	20.76	62.73	9.40	7.11	4.17
Matra	12.27	20.31	63.50	8.97	7.23	4.18
Valiant	11.25	19.91	64.05	8.92	7.12	4.20
Barley						
Camargue	8.04	18.50	66.12	8.07	7.31	4.05
Maghee	10.97	18.47	67.83	6.36	7.35	4.22
Marinka	9.81	19.53	65.93	7.47	7.06	3.82
Pastoral	10.97	19.17	66.10	7.46	7.27	4.05
Wheat						
Salibi	12.21	20.00	66.62	6.34	7.03	4.32
Trial 2nd						
Oats						
Adamo	6.50	20.27	62.87	10.48	6.38	3.52
Dula	6.72	20.13	64.09	9.38	6.39	3.46
Matra	5.78	19.95	64.86	8.96	6.23	3.40
Valiant	6.77	20.03	64.08	9.52	6.37	3.57
Barley						
Camargue	7.35	17.38	70.26	6.25	6.11	3.44
Maghee	7.49	17.70	69.79	6.32	6.19	3.47
Marinka	7.30	19.57	68.26	6.15	6.02	3.44
Pastoral	6.58	18.82	69.41	5.71	6.05	3.41
Wheat						
Salibi	5.97	20.49	66.85	6.35	6.31	3.45
Trial 3rd						
Oats						
Adamo	6.99	21.07	61.58	10.78	6.57	3.54
Dula	7.17	20.89	62.85	9.61	6.64	3.48
Matra	6.62	21.58	61.93	9.92	6.57	3.43
Valiant	7.12	21.13	62.28	10.10	6.48	3.58
Barley						
Camargue	7.87	18.64	68.31	6.83	6.22	3.46
Maghee	8.06	18.31	68.29	7.18	6.22	3.49
Marinka	8.50	19.62	67.43	6.81	6.14	3.49
Pastoral	7.68	19.54	67.53	6.74	6.19	3.46
Wheat						
Salibi	8.39	20.47	66.76	6.56	6.21	3.54

[a] Data was calculated on dry matter basis.

Results are average of two determinations performed on each sample.

Appendix II Carbohydrate based content (g 100 g^{-1})^{a} of Kishk made with different cereal Burghols.

Kishk samples	Starch	Free sugar	Fibre	β-Glucan	Phytic Acid
Trial 1st					
Oats					
Adamo	39.10	9.79	8.07	2.18	0.72
Dula	41.19	10.30	6.33	2.42	0.78
Matra	41.31	10.26	7.51	1.40	0.85
Valiant	42.47	9.86	6.25	1.70	0.73
Barley					
Camargue	45.38	7.84	7.34	1.64	0.53
Maghee	44.47	8.67	9.39	1.39	0.56
Marinka	43.15	9.70	7.97	2.00	0.55
Pastoral	44.16	9.82	7.30	1.89	0.52
Wheat					
Salibi	40.47	11.09	8.75	1.27	0.51
Trial 2nd					
Oats					
Adamo	39.41	6.15	5.95	2.20	0.61
Dula	37.54	8.84	7.29	2.52	0.82
Matra	40.20	9.29	6.21	2.31	0.84
Valiant	42.50	8.18	6.29	1.70	0.68
Barley					
Camargue	45.95	6.48	7.64	1.71	0.39
Maghee	43.64	6.22	9.09	1.52	0.45
Marinka	44.18	5.93	9.93	2.22	0.38
Pastoral	46.31	6.69	8.97	1.57	0.40
Wheat					
Salibi	41.60	10.10	9.05	0.75	0.45
Trial 3rd					
Oats					
Adamo	38.57	7.83	5.77	2.21	0.67
Dula	38.57	8.41	7.81	2.66	0.50
Matra	40.65	9.91	7.04	2.58	0.80
Valiant	42.15	8.20	5.91	2.28	0.67
Barley					
Camargue	44.13	7.98	7.08	1.85	0.54
Maghee	42.52	6.36	9.39	1.79	0.52
Marinka	43.70	7.63	9.02	2.44	0.40
Pastoral	43.38	7.85	7.37	1.97	0.44
Wheat					
Salibi	40.44	8.29	9.15	1.28	0.49

[a] Data was calculated on dry matter basis.

Results are average of two determinations performed on each sample.

Appendix III Mineral contents (mg 100 g^{-1})^{a} of Kishk made with different cereal Burghols.

Kishk samples	Ca	P	Mg	K	Na	Cu	Zn	Fe	Mn
Trial 1st									
Oats									
Adamo	370	610	110	789	1590	0.25	3.25	5.20	2.80
Dula	390	610	120	793	1470	0.23	3.40	8.96	3.34
Matra	420	610	120	739	1500	0.31	3.77	7.14	3.42
Valiant	360	580	100	781	1590	0.34	3.52	5.45	3.39
Barley									
Camargue	390	560	100	782	1650	0.31	2.92	10.20	1.22
Maghee	370	550	100	768	1640	0.33	3.74	5.50	1.21
Marinka	360	550	90	756	1550	0.25	3.64	4.80	1.60
Pastoral	360	530	90	809	1600	0.33	2.71	5.33	0.88
Wheat									
Salibi	380	500	100	781	1530	0.35	3.33	13.20	1.81
Trial 2nd									
Oats									
Adamo	436	570	119	753	1150	0.06	3.36	7.45	2.16
Dula	471	619	136	771	1208	0.12	3.60	7.15	3.11
Matra	494	635	136	783	1235	0.26	3.86	12.36	3.03
Valiant	490	632	120	833	1289	0.36	3.75	7.79	3.08
Barley									
Camargue	434	551	111	810	1242	0.36	2.61	7.72	0.65
Maghee	446	547	110	779	1213	0.23	3.19	8.96	0.55
Marinka	440	536	105	773	1168	0.28	3.00	8.19	0.65
Pastoral	395	501	104	776	1134	0.41	2.62	8.50	0.55
Wheat									
Salibi	466	587	126	851	1290	0.55	3.36	32.98	1.57
Trial 3rd									
Oats									
Adamo	501	653	136	738	1305	0.24	4.02	10.07	2.62
Dula	524	685	154	719	1340	0.21	4.44	15.00	3.46
Matra	541	686	154	702	1340	0.31	4.78	10.69	3.67
Valiant	515	658	133	665	1305	0.32	4.70	14.35	3.80
Barley									
Camargue	492	603	121	671	1305	0.27	3.36	9.06	0.82
Maghee	496	566	121	674	1270	0.30	4.02	9.17	0.71
Marinka	458	540	109	660	1210	0.23	3.71	6.59	0.82
Pastoral	463	551	118	782	1290	0.33	3.24	7.54	0.70
Wheat									
Salibi	472	568	121	766	1260	0.36	4.11	18.57	1.79

[a] Data was calculated on dry matter basis.

Results are average of two determinations performed on each sample.

Appendix IV Fatty acids concentrations (w/w.%)[a] of Kishk made with different cereal Burghols.

Kishk samples	Butyric C 4:0	Caproic C 6:0	Caprylic C 8:0	Capric C :10	Lauric C :12	Myristic C 14:0	Palmitic C 16:0	Stearic C 18:0	Oleic C 18:1	Linoleic C 18:2	Linolenic C 18:3
Trial 1st											
Oats											
Adamo	1.09	1.11	0.69	1.63	1.89	7.74	22.81	7.36	38.35	14.54	2.80
Dula	1.38	1.48	0.90	1.98	2.27	8.27	24.82	7.20	35.88	13.04	2.79
Matra	1.57	1.53	0.91	2.04	2.35	8.26	25.00	9.01	33.30	12.88	3.15
Valiant	1.42	1.48	0.90	2.03	2.28	7.77	24.57	7.97	34.65	14.05	2.88
Barley											
Camargue	2.01	1.76	1.04	2.56	3.03	10.89	28.65	10.67	27.72	8.62	3.05
Maghee	2.11	1.84	1.11	2.61	3.02	10.54	28.71	10.39	27.99	8.65	3.04
Marinka	1.88	1.84	1.16	2.70	3.08	10.76	29.31	10.45	27.98	7.88	2.96
Pastoral	2.46	2.02	1.22	2.86	3.24	11.03	29.07	10.41	27.24	8.17	2.28
Wheat											
Salibi	1.52	1.43	0.97	2.40	2.87	10.25	26.60	10.19	27.85	12.85	3.06
Trial 2nd											
Oats											
Adamo	1.54	1.59	1.18	1.99	2.46	7.87	23.39	6.35	35.99	15.65	2.00
Dula	1.68	1.70	1.04	2.32	2.92	10.48	26.48	6.51	32.06	12.84	1.97
Matra	2.15	2.06	1.22	2.45	3.04	10.45	27.12	6.43	30.35	12.90	1.83
Valiant	2.28	2.01	1.15	2.42	2.96	9.49	26.96	7.17	32.07	11.72	1.77
Barley											
Camargue	2.29	1.94	1.22	2.79	3.48	11.57	28.87	9.48	23.94	11.42	2.99
Maghee	2.23	1.93	1.17	2.80	3.49	11.58	28.99	9.26	24.58	11.72	2.25
Marinka	2.24	2.07	1.26	3.01	3.80	12.55	31.62	9.51	24.81	8.90	0.25
Pastoral	2.21	1.90	1.14	2.76	3.43	11.55	29.65	8.85	23.81	12.48	2.23
Wheat											
Salibi	2.45	2.09	1.29	2.88	3.45	11.60	27.52	9.11	24.09	12.48	3.04
Trial 3rd											
Oats											
Adamo	1.34	1.24	0.74	1.84	2.26	10.08	22.30	6.65	37.46	14.92	1.18
Dula	1.35	1.52	0.90	2.03	2.43	10.07	27.56	6.73	33.04	12.90	1.47
Matra	1.76	1.35	0.76	2.17	2.79	11.99	24.28	8.02	34.26	11.65	0.99
Valiant	1.70	1.34	1.00	2.13	2.77	12.50	24.90	7.90	32.26	12.82	0.69
Barley											
Camargue	2.31	2.17	0.96	3.91	3.72	13.84	29.61	5.59	22.19	14.35	1.35
Maghee	3.06	1.99	1.13	3.09	3.73	13.87	28.41	7.48	24.81	11.47	0.97
Marinka	1.62	1.97	1.11	3.29	3.49	13.14	33.37	6.42	21.76	12.63	1.21
Pastoral	2.82	2.04	1.14	3.35	3.67	14.96	30.22	7.39	22.82	9.72	1.86
Wheat											
Salibi	1.44	1.61	0.84	3.43	3.15	11.30	28.94	7.23	25.51	13.98	2.57

[a] Data was calculated on weight of fat.

Results are average of two determinations performed on each sample.

Appendix V Total fatty acids concentrations (w/w.%)[a] of Kishk made with different cereal Burghols.

Kishk samples	Saturated	Mono-unsaturated	Poly-unsaturated
Trial 1st			
Oats			
Adamo	44.31	38.35	17.33
Dula	48.29	35.88	15.83
Matra	50.67	33.30	16.04
Valiant	48.43	34.65	16.92
Barley			
Camargue	60.61	27.72	11.67
Maghee	60.32	27.99	11.68
Marinka	61.19	27.98	10.84
Pastoral	62.31	27.24	10.45
Wheat			
Salibi	56.24	27.85	15.92
Trial 2nd			
Oats			
Adamo	46.35	35.99	17.66
Dula	53.13	32.06	14.81
Matra	54.92	30.35	14.73
Valiant	54.44	32.07	13.49
Barley			
Camargue	61.65	23.94	14.41
Maghee	61.45	24.58	13.97
Marinka	66.05	24.81	9.15
Pastoral	61.48	23.81	14.71
Wheat			
Salibi	60.39	24.09	15.51
Trial 3rd			
Oats			
Adamo	46.44	37.46	16.10
Dula	52.59	33.04	14.37
Matra	53.11	34.26	12.64
Valiant	54.24	32.26	13.50
Barley			
Camargue	62.10	22.19	15.71
Maghee	62.75	24.81	12.44
Marinka	64.41	21.76	13.84
Pastoral	65.59	22.82	11.59
Wheat			
Salibi	57.95	25.51	16.54

[a] Data was calculated on weight of fat.

Results are average of two determinations performed on each sample.

Appendix VI Organic acids contents (μg g^{-1}) of Kishk made with different cereal Burghols.

Kishk samples	Orotic	Citric	Pyruvic	Lactic	Uric/Formic	Acetic	Hippuric
Trial 1st							
Oats							
Adamo	21	277	27	18516	11	29	32
Dula	23	264	22	19765	12	50	46
Matra	29	362	23	20271	13	58	43
Valiant	24	268	23	19655	10	73	47
Barley							
Camargue	20	310	60	16902	14	47	34
Maghee	20	156	30	18665	15	45	37
Marinka	18	257	37	19674	14	53	44
Pastoral	21	316	41	17937	17	61	44
Wheat							
Salibi	16	235	33	18355	24	54	33
Trial 2nd							
Oats							
Adamo	22	163	60	20112	16	59	37
Dula	21	144	62	19747	12	46	41
Matra	18	129	58	20027	11	27	37
Valiant	21	139	66	20171	14	54	31
Barley							
Camargue	29	234	75	19422	19	53	31
Maghee	26	180	72	18166	21	56	31
Marinka	28	204	68	19050	21	58	32
Pastoral	27	193	52	18848	24	90	31
Wheat							
Salibi	21	127	71	19978	23	66	34
Trial 3rd							
Oats							
Adamo	39	315	45	20748	24	39	43
Dula	34	279	69	18877	19	50	44
Matra	37	323	51	21441	24	42	34
Valiant	36	274	31	20811	17	60	38
Barley							
Camargue	38	321	45	20485	26	17	40
Maghee	34	276	42	20943	27	59	42
Marinka	31	240	27	19758	28	56	32
Pastoral	30	223	30	18173	31	87	33
Wheat							
Salibi	32	275	45	19450	26	71	35

Results are average of two determinations performed on each sample.

Appendix VII Gel formation and pH change in milk using different percentages of D-glucono-δ-lactone at 5°C and 45°C.

GDL	5°C				45°C			
	pH				pH			
(g 100 g^{-1})	Start	End	Time (h)	After over night cold storage at 5-8°C	Start	End	Time (h)	After over night cold storage at 5-8° C
Trial 1st								
2	6.31	5.10	7	4.53	6.14	4.61	4	4.24
4	5.99	4.70	3	3.56	5.86	3.92	3	3.53
6	5.85	4.25	3	3.31	5.66	3.50	3	3.23
8	5.65	4.14	2	3.03	5.56	3.38	3	3.10
10	5.55	3.85	2	2.90	5.35	3.08	3	-
12	5.60	3.99	2	2.94	5.32	2.98	3	-
14	5.56	3.79	2	-[a]	5.19	2.88	2	-
16	5.40	3.52	2	-	5.21	2.86	2	-
18	5.32	3.37	2	-	5.09	2.97	2	-
20	5.27	3.30	2	-	5.07	2.88	2	-
Trial 2nd								
2	6.43	4.60	7	4.36	6.46	4.06	4	4.11
4	6.39	3.67	3	3.58	6.37	3.51	3	3.50
6	6.31	3.34	3	2.23	6.32	3.25	3	3.19
8	6.22	3.08	1	-	6.17	3.06	1	-
10	6.05	2.91	1	-	6.10	2.95	1	-
12	6.07	2.78	1	-	5.98	2.86	1	-
14	5.93	2.70	1	-	5.89	2.79	1	-
16	5.91	2.62	1	-	5.81	2.70	1	-
18	5.85	2.53	1	-	5.86	2.67	1	-
20	5.73	2.48	1	-	5.66	2.59	1	-

[a] Not cold stored over night.

Appendix VIII Chemical composition (g 100 g^{-1})[a] of Kishk made from different cereals, acidulants and 'milk'.

Cereal base	Moisture			Fat			Protein			Carbohydrate			Ash			Salt		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Trial 1st																		
Supplier A																		
Porridge oats	7.86	7.57	7.26	10.08	8.27	10.11	18.97	19.07	19.56	67.27	66.61	64.25	3.68	6.06	6.09	-[e]	3.26	3.18
Oats flour	7.84	8.42	6.86	10.38	8.28	10.21	19.57	19.06	19.01	66.35	66.64	64.70	3.70	6.03	6.09	-	3.21	3.20
Burghol	9.90	9.60	8.89	5.75	4.02	6.69	21.56	20.93	20.90	69.13	69.17	66.32	3.55	5.89	6.09	-	3.23	3.21
Wheat flour	12.28	10.59	8.22	5.79	3.71	6.92	19.93	18.97	21.10	70.98	71.66	65.68	3.30	5.66	6.31	-	3.20	3.18
Supplier B																		
Porridge oats	8.94	10.88	10.77	11.32	9.48	10.37	19.55	18.83	19.99	65.50	65.78	63.27	3.64	5.91	6.37	-	3.20	3.31
Oats flour	8.02	10.48	13.15	8.97	9.80	9.03	19.52	19.08	19.63	67.96	65.35	65.08	3.56	5.77	6.26	-	3.14	3.22
Burghol	9.62	8.41	8.72	5.87	3.31	7.48	20.93	20.06	20.13	69.74	70.64	66.32	3.47	5.99	6.07	-	3.26	3.23
Wheat flour	12.02	10.06	8.72	5.66	2.90	6.81	19.46	18.94	20.77	71.46	72.39	66.22	3.42	5.77	6.21	-	3.23	3.28
Trial 2nd																		
Supplier A																		
Porridge oats	8.56	8.82	8.71	10.22	7.67	10.98	18.98	18.12	19.37	67.21	68.22	63.62	3.59	5.99	6.04	-	3.18	3.17
Oats flour	8.28	9.25	9.73	9.89	7.18	10.67	19.81	18.59	18.87	66.68	68.28	64.44	3.63	5.96	6.03	-	3.10	3.12
Burghol	9.42	10.49	9.90	5.92	4.14	5.87	21.39	19.99	21.78	69.17	70.17	66.28	3.52	5.71	6.08	-	3.18	3.22
Wheat flour	12.74	10.27	7.94	5.64	4.28	5.76	19.82	18.80	22.12	71.31	71.40	65.55	3.23	5.53	6.57	-	3.11	3.27
Supplier B																		
Porridge oats	9.20	9.31	9.62	10.99	9.21	10.50	19.42	18.93	18.99	65.88	65.75	64.37	3.72	6.11	6.15	-	3.18	3.26
Oats flour	9.15	10.04	10.32	8.17	9.37	9.47	19.45	18.00	19.04	68.75	66.72	65.35	3.63	5.91	6.14	-	3.18	3.27
Burghol	9.23	8.32	8.93	5.85	3.39	6.74	21.01	19.69	21.45	69.76	71.28	65.53	3.39	5.64	6.28	-	3.22	3.24
Wheat flour	11.19	9.80	8.59	5.21	3.32	6.45	19.57	18.36	21.18	72.13	72.88	65.99	3.09	5.44	6.38	-	3.21	3.25

[a] Data was calculated on dry matter basis. [b] 'Milk'. [c] GDL. [d] Yoghurt. [e] No salt added.

Results are average of two determinations performed on each sample.

Appendix IX Carbohydrate-based content (g 100 g^{-1})[a] of Kishk made from different cereals, acidulants and 'milk'.

Cereal base	Starch			Free sugar			Fibre			β-glucan			Phytic acid		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Trial 1st															
Supplier A															
Porridge oats	41.34	40.20	40.82	13.26	12.54	11.04	7.00	5.71	6.79	2.12	3.89	3.11	0.64	0.65	0.59
Oats flour	40.12	41.24	39.28	13.57	11.66	10.80	5.53	5.64	5.83	1.60	3.07	2.65	0.73	0.86	0.68
Burghol	42.52	38.33	39.31	13.17	12.79	10.48	7.02	5.91	6.66	0.30	1.37	0.78	0.77	0.68	0.62
Wheat flour	44.98	39.93	44.89	15.72	15.80	8.03	2.55	3.13	3.54	0.51	0.55	1.63	0.44	0.10	0.16
Supplier B															
Porridge oats	37.07	38.74	43.73	12.84	13.22	8.85	5.91	5.87	5.63	2.57	3.13	2.50	0.67	0.67	0.57
Oats flour	42.74	39.16	42.52	13.05	12.93	8.11	4.78	5.25	3.88	1.34	3.47	2.54	0.59	0.43	0.30
Burghol	36.72	33.05	37.58	12.55	13.38	10.36	6.36	5.57	5.40	0.19	1.58	1.09	0.61	0.59	0.63
Wheat flour	40.38	36.89	40.23	15.74	16.22	7.55	2.03	2.75	2.79	0.63	0.42	1.58	0.27	0.10	0.12
Trial 2nd															
Supplier A															
Porridge oats	42.54	40.87	43.37	13.12	12.15	9.90	5.61	5.60	5.76	2.13	3.72	3.57	0.64	0.55	0.57
Oats flour	40.84	40.17	40.61	13.03	11.69	10.07	5.37	5.57	4.99	1.99	3.42	2.59	0.64	0.71	0.58
Burghol	40.75	38.21	42.12	13.12	12.77	10.29	6.72	6.45	7.68	0.26	1.67	0.88	0.66	0.57	0.66
Wheat flour	43.83	39.54	46.45	16.39	16.64	7.97	3.70	3.50	3.57	0.44	0.68	1.62	0.53	0.17	0.13
Supplier B															
Porridge oats	39.20	39.63	39.50	13.42	13.73	9.30	7.17	6.65	6.65	2.29	3.46	2.39	0.73	0.70	0.60
Oats flour	41.71	40.37	41.55	13.15	12.88	7.59	5.70	6.51	5.11	1.59	3.34	2.28	0.68	0.54	0.29
Burghol	37.72	32.48	38.43	12.25	12.14	10.74	6.93	7.71	7.16	0.30	1.13	1.22	0.68	0.50	0.71
Wheat flour	41.74	37.53	39.36	15.39	15.57	7.47	3.69	2.58	2.84	0.61	0.56	1.40	0.36	0.16	0.19

[a] Data was calculated on dry matter basis. [b] 'Milk'. [c] GDL. [d] Yoghurt.

Results are average of two determinations performed on each sample.

Appendix X Mineral contents (mg 100 g^{-1})[a] of Kishk made from different cereals, acidulants and 'milk'.

Cereal base	Ca			P			Mg		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y
Trial 1st									
Supplier A									
Porridge oats	480	490	470	630	620	620	120	120	120
Oats flour	470	450	470	660	610	630	130	120	120
Burghol	450	440	460	530	500	520	100	90	100
Wheat flour	450	430	480	500	470	530	80	70	80
Supplier B									
Porridge oats	450	430	460	610	580	630	120	110	120
Oats flour	460	420	460	590	540	590	100	100	100
Burghol	460	450	460	520	500	520	100	100	100
Wheat flour	440	440	480	450	440	480	70	70	80
Trial 2nd									
Supplier A									
Porridge oats	450	440	450	590	580	600	110	110	110
Oats flour	450	480	450	620	830	620	120	120	120
Burghol	460	440	470	530	490	530	100	100	100
Wheat flour	440	430	510	480	470	560	80	80	90
Supplier B									
Porridge oats	510	460	450	640	590	590	120	110	120
Oats flour	490	430	460	580	540	560	100	100	100
Burghol	460	490	500	520	430	550	100	90	110
Wheat flour	450	420	430	460	420	480	80	70	100

Cereal base	K			Na			Cu		
	M	D	Y	M	D	Y	M	D	Y
Trial 1st									
Supplier A									
Porridge oats	805	781	804	143	1180	1170	0.29	0.28	0.27
Oats flour	815	770	814	145	1160	1150	0.25	0.24	0.25
Burghol	743	740	753	143	1130	1170	0.30	0.29	0.30
Wheat flour	709	688	774	143	1130	1260	0.25	0.22	0.25
Supplier B									
Porridge oats	780	723	800	141	1120	1190	0.26	0.23	0.25
Oats flour	763	711	767	143	1110	1240	0.58	0.24	0.23
Burghol	727	735	759	151	1170	1180	0.29	0.29	1.05
Wheat flour	692	687	747	141	1150	1250	0.20	0.20	1.12
Trial 2nd									
Supplier A									
Porridge oats	767	752	754	143	1100	1130	0.25	0.28	0.22
Oats flour	789	786	776	138	1300	1130	0.27	0.23	0.32
Burghol	757	705	766	147	1080	1170	0.29	0.27	0.29
Wheat flour	714	704	801	142	1130	1320	0.24	0.22	0.31
Supplier B									
Porridge oats	809	770	778	166	1120	1130	0.24	0.22	0.23
Oats flour	796	722	782	170	1120	1160	0.23	0.34	0.23
Burghol	739	760	761	142	1450	1250	0.30	0.28	0.30
Wheat flour	689	643	688	140	1130	1090	0.20	0.19	0.23

Cereal base	Zn			Fe			Mn		
	M	D	Y	M	D	Y	M	D	Y
Trial 1st									
Supplier A									
Porridge oats	4.06	3.72	3.75	4.67	3.95	4.36	3.45	3.34	3.45
Oats flour	4.36	3.77	3.95	7.25	4.05	4.56	3.35	3.24	3.34
Burghol	3.56	3.34	3.36	3.12	2.70	3.01	1.31	1.31	1.41
Wheat flour	2.95	2.98	3.24	1.52	1.80	2.11	0.91	0.90	1.01
Supplier B									
Porridge oats	3.70	3.13	3.61	3.75	3.53	3.83	2.83	2.72	3.03
Oats flour	3.60	3.40	3.77	4.14	3.82	3.53	2.93	2.72	3.03
Burghol	3.29	2.93	3.26	2.49	2.67	4.07	1.20	1.10	1.20
Wheat flour	2.48	2.64	3.02	1.00	1.47	2.28	0.40	0.40	0.50
Trial 2nd									
Supplier A									
Porridge oats	3.57	3.42	3.45	3.85	4.56	3.84	3.20	3.22	3.10
Oats flour	3.85	3.48	3.93	4.74	3.23	3.74	3.30	3.11	3.19
Burghol	3.18	3.03	3.16	2.57	2.34	2.86	1.27	1.27	1.27
Wheat flour	2.63	2.67	3.22	0.96	1.34	2.05	0.86	0.86	0.96
Supplier B									
Porridge oats	3.98	3.14	3.32	4.44	3.50	3.01	2.81	2.80	2.80
Oats flour	4.21	3.27	3.42	5.34	3.49	3.30	3.01	2.90	3.01
Burghol	3.20	2.89	3.20	2.43	2.40	2.52	1.17	1.06	1.16
Wheat flour	2.45	2.39	2.69	1.22	1.20	2.01	0.36	0.35	0.46

[a] Data was calculated on dry matter basis. [b] 'Milk'. [c] GDL. [d] Yoghurt.

Results are average of two determinations performed on each sample.

Appendix XI Organic acids contents ($\mu g\ g^{-1}$) of acidulants (GDL and yoghurt) and 'milk'.

Product	Orotic	Citric	Pyruvic	Lactic	Uric/Formic	Acetic	Hippuric
Trial Ist							
'Milk'	62.4	895.6	4.3	187.5	14.5	17.0	11.3
GDL	57.3	889.9	-[a]	204.6	18.1	7.6	7.5
Yoghurt	55.9	741.9	27.8	7392.0	25.0	137.9	5.4
Trial 2nd							
'Milk'	60.8	876.5	6.4	192.3	14.5	16.8	10.4
GDL	51.0	747.8	-	192.5	16.9	10.3	8.5
Yoghurt	54.4	699.0	25.9	6902.4	23.4	122.3	5.1

[a] Not detected.

Results are average of two determinations performed on each sample.

Appendix XII Organic acids contents ($\mu g\ g^{-1}$) of Kishk made from different cereals, acidulants and 'milk'.

Cereal base	Orotic			Citric			Pyruvic			Lactic			Uric/formic			Acetic			Propionic			Hippuric		
	M[a]	D[b]	Y[c]	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Trial 1st																								
Supplier A																								
Porridge oats	37	7	12	36	12	44	5	6	4	22	6343	10266	14	16	18	18	1447	274	111	3376	820	23	29	27
Oats flour	37	10	12	46	16	50	5	8	4	88	6240	7939	15	17	16	63	1408	195	142	2597	726	22	28	19
Burghol	32	12	10	35	18	44	7	20	19	100	3962	8685	33	27	46	84	2257	227	227	959	175	21	27	22
Wheat flour	25	8	9	25	14	59	0	0	21	291	9066	7502	26	53	40	306	1099	137	693	1783	186	13	5	14
Supplier B																								
Porridge oats	34	12	13	36	16	59	4	13	4	50	3816	10463	13	15	16	31	1866	158	290	1178	598	17	18	19
Oats flour	38	13	14	47	28	76	4	16	5	103	4855	9853	16	18	18	67	1078	152	207	896	556	18	0	17
Burghol	26	9	9	46	20	48	4	21	16	124	3751	9706	23	23	26	48	2126	355	262	706	226	10	13	17
Wheat flour	24	8	12	53	19	55	0	3	30	80	4397	8890	20	13	21	139	1784	210	360	1336	119	13	21	17
Trial 2nd																								
Supplier A																								
Porridge oats	36	9	12	57	21	48	5	0	3	24	7484	10279	13	15	15	49	875	163	170	1560	672	22	0	20
Oats flour	33	11	13	46	31	53	4	0	4	171	7975	10278	13	17	18	53	909	232	215	1280	709	20	4	19
Burghol	25	12	12	43	23	48	8	13	16	123	3721	9574	27	26	28	77	2365	197	157	499	187	13	20	18
Wheat flour	25	8	12	42	19	80	0	2	24	74	4415	9972	25	16	23	328	2531	198	536	2149	232	13	23	18
Supplier B																								
Porridge oats	36	13	12	68	27	49	3	0	7	104	3376	10344	12	14	15	24	1114	118	988	1005	603	10	0	20
Oats flour	39	12	13	58	27	72	4	13	3	307	3735	9964	16	16	19	40	1098	134	1203	891	449	18	0	20
Burghol	28	11	12	38	23	39	5	9	14	165	3741	9944	23	23	27	67	1633	425	305	671	174	11	26	23
Wheat flour	22	9	10	48	21	38	2	4	19	96	4018	9090	16	13	12	119	1349	177	490	1177	144	12	22	22

[a] 'Milk'. [b] GDL. [c] Yoghurt.
Results are average of two determinations performed on each sample.

Appendix XIII Microbiological quality (cfu g^{-1}) of Kishk made from different cereals, acidulants and 'milk'.

Cereal base/ storage time	Total colony count			Coliforms			Yeasts and moulds			Aerobic spore-formers: Mesophiles			Aerobic spore-formers: Thermophiles		
	M[a]	D[b]	Y[c]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Fresh															
Trial 1st															
Supplier A															
Porridge oats	$2.5x10^{6}$	$3.0x10^{4}$	$5.3x10^{4}$	<10[d]	<10	<10	<10	$6.5x10^{2}$	$6.0x10^{3}$	$1.3x10^{2}$	$3.2x10^{2}$	$1.6x10^{2}$	$3.2x10^{2}$	$1.9x10^{2}$	$1.4x10^{2}$
Oats flour	$1.3x10^{6}$	$4.3x10^{4}$	$5.2x10^{3}$	<10	<10	<10	<10	$1.7x10^{3}$	<10	$2.9x10^{2}$	$2.3x10^{2}$	$1.2x10^{2}$	$1.5x10^{2}$	$1.5x10^{2}$	<10
Burghol	$2.5x10^{6}$	$7.3x10^{4}$	$1.3x10^{6}$	<10	<10	<10	<10	<10	<10	$3.9x10^{3}$	$2.2x10^{3}$	$8.9x10^{3}$	$3.9x10^{3}$	$4.4x10^{2}$	$2.6x10^{3}$
Wheat flour	$6.1x10^{5}$	$1.2x10^{4}$	$1.7x10^{4}$	<10	<10	<10	<10	<10	<10	$1.3x10^{3}$	$4.2x10^{3}$	$4.6x10^{3}$	<10	<10	<10
Supplier B															
Porridge oats	$2.0x10^{5}$	$1.4x10^{4}$	$1.5x10^{5}$	<10	<10	<10	<10	<10	$6.8x10^{2}$	<10	$2.0x10^{2}$	$2.0x10^{2}$	$2.5x10^{2}$	$2.1x10^{2}$	$2.6x10^{2}$
Oats flour	$1.5x10^{6}$	$8.3x10^{3}$	$5.6x10^{4}$	<10	<10	<10	<10	<10	$4.2x10^{2}$	$3.0x10^{2}$	$2.6x10^{2}$	$2.3x10^{2}$	$1.4x10^{2}$	$1.5x10^{2}$	<10
Burghol	$2.9x10^{6}$	$1.6x10^{6}$	$2.8x10^{6}$	<10	<10	<10	<10	<10	<10	$5.1x10^{3}$	$6.6x10^{3}$	$5.7x10^{3}$	$2.6x10^{2}$	$2.5x10^{2}$	$4.0x10^{3}$
Wheat flour	$3.0x10^{5}$	$3.4x10^{4}$	$1.2x10^{4}$	<10	<10	<10	<10	<10	<10	<10	$4.4x10^{3}$	$2.9x10^{2}$	<10	<10	<10
Trial 2nd															
Supplier A															
Porridge oats	$2.1x10^{6}$	$4.8x10^{4}$	$8.2x10^{4}$	<10	<10	<10	<10	$3.6x10^{2}$	$1.2x10^{2}$	$1.7x10^{2}$	$2.5x10^{2}$	$1.4x10^{2}$	$1.2x10^{2}$	$3.1x10^{2}$	$1.6x10^{2}$
Oats flour	$2.3x10^{6}$	$5.8x10^{4}$	$1.7x10^{4}$	<10	<10	<10	<10	$1.3x10^{3}$	<10	$2.4x10^{2}$	$2.7x10^{2}$	$2.0x10^{2}$	$1.9x10^{2}$	$2.3x10^{2}$	<10
Burghol	$2.5x10^{6}$	$1.3x10^{5}$	$1.9x10^{6}$	<10	<10	<10	<10	<10	<10	$8.2x10^{3}$	$1.9x10^{3}$	$3.9x10^{3}$	$2.5x10^{3}$	$4.6x10^{2}$	$5.3x10^{3}$
Wheat flour	$3.7x10^{5}$	$2.4x10^{4}$	$5.8x10^{4}$	<10	<10	<10	<10	<10	<10	$1.1x10^{3}$	<10	$1.0x10^{2}$	<10	<10	<10
Supplier B															
Porridge oats	$3.1x10^{5}$	$4.7x10^{4}$	$3.3x10^{5}$	<10	<10	<10	<10	<10	<10	$1.2x10^{2}$	$2.7x10^{2}$	$3.0x10^{2}$	$4.2x10^{2}$	$4.2x10^{2}$	$1.9x10^{2}$
Oats flour	$1.4x10^{6}$	$5.6x10^{4}$	$4.3x10^{4}$	<10	<10	<10	<10	<10	<10	$2.3x10^{2}$	$4.1x10^{2}$	$2.1x10^{2}$	$1.5x10^{2}$	$2.7x10^{2}$	<10
Burghol	$2.6x10^{6}$	$1.4x10^{6}$	$2.5x10^{6}$	<10	<10	<10	<10	<10	<10	$7.3x10^{3}$	$4.6x10^{3}$	$4.5x10^{3}$	$4.8x10^{2}$	$4.9x10^{3}$	$4.1x10^{3}$
Wheat flour	$4.6x10^{5}$	$3.3x10^{4}$	$1.7x10^{4}$	<10	<10	<10	<10	<10	<10	<10	$2.5x10^{2}$	$1.7x10^{2}$	<10	<10	<10

Appendix XIII (continued)

Cereal base/ storage time	Total colony count			Coliforms			Yeasts and moulds			Aerobic spore-formers: Mesophiles			Aerobic spore-formers: Thermophiles		
	M[a]	D[b]	Y[c]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
6 Month															
Trial 1st															
Supplier A															
Porridge oats	$2.5x10^6$	$7.7x10^3$	$5.6x10^4$	<10	<10	<10	<10	<10	<10	$3.4x10^2$	$4.2x10^2$	$1.5x10^2$	$1.7x10^2$	$2.0x10^2$	<10
Oats flour	$7.1x10^5$	$1.8x10^4$	$7.8x10^4$	<10	<10	<10	<10	<10	<10	$2.6x10^2$	$4.2x10^2$	$1.3x10^2$	$1.3x10^2$	$1.1x10^2$	<10
Burghol	$2.7x10^6$	$2.4x10^4$	$1.7x10^5$	<10	<10	<10	<10	<10	<10	$5.4x10^3$	$3.5x10^3$	$4.0x10^3$	$7.7x10^3$	$3.5x10^3$	$5.1x10^3$
Wheat flour	$1.8x10^5$	$9.4x10^4$	$1.8x10^4$	<10	<10	<10	<10	<10	<10	$2.7x10^3$	$5.4x10^3$	$4.7x10^3$	<10	<10	<10
Supplier B															
Porridge oats	$1.3x10^5$	$2.6x10^4$	$1.6x10^4$	<10	<10	<10	<10	<10	<10	$3.5x10^2$	$1.4x10^2$	$2.3x10^3$	$3.8x10^2$	<10	$2.1x10^2$
Oats flour	$1.5x10^6$	$7.1x10^3$	$2.4x10^4$	<10	<10	<10	<10	<10	<10	$1.8x10^2$	$2.9x10^2$	$2.0x10^2$	$1.4x10^2$	$1.2x10^2$	<10
Burghol	$2.6x10^6$	$4.7x10^4$	$1.5x10^6$	<10	<10	<10	<10	<10	<10	$9.0x10^3$	$7.7x10^3$	$4.8x10^3$	$5.0x10^2$	$4.3x10^3$	$3.0x10^3$
Wheat flour	$2.3x10^5$	$4.1x10^4$	$1.6x10^4$	<10	<10	<10	<10	<10	<10	<10	$3.8x10^2$	$2.8x10^2$	<10	<10	<10
Trial 2nd															
Supplier A															
Porridge oats	$2.1x10^6$	$2.4x10^4$	$7.4x10^4$	<10	<10	<10	<10	<10	<10	$4.8x10^3$	$6.8x10^3$	$3.3x10^2$	$2.0x10^2$	$2.4x10^2$	$1.1x10^2$
Oats flour	$8.5x10^5$	$5.5x10^4$	$2.7x10^4$	<10	<10	<10	<10	<10	<10	$2.9x10^2$	$4.5x10^2$	$2.0x10^2$	$2.3x10^2$	$1.7x10^2$	<10
Burghol	$2.8x10^6$	$4.3x10^4$	$3.7x10^5$	<10	<10	<10	<10	<10	<10	$5.9x10^3$	$1.5x10^3$	$3.5x10^3$	$3.9x10^3$	$3.9x10^3$	$4.9x10^3$
Wheat flour	$4.1x10^4$	$3.9x10^4$	$2.1x10^4$	<10	<10	<10	<10	<10	<10	$3.2x10^2$	$7.2x10^3$	$5.4x10^2$	<10	<10	$1.0x10^2$
Supplier B															
Porridge oats	$1.7x10^5$	$6.5x10^4$	$2.1x10^5$	<10	<10	<10	<10	<10	<10	$2.3x10^2$	$5.8x10^3$	$4.5x10^3$	$4.8x10^2$	$3.9x10^2$	$1.6x10^2$
Oats flour	$1.3x10^6$	$2.9x10^4$	$1.5x10^4$	<10	<10	<10	<10	<10	<10	$4.6x10^2$	$1.0x10^3$	$4.0x10^3$	$1.3x10^2$	$2.0x10^2$	$1.7x10^2$
Burghol	$2.8x10^6$	$1.6x10^5$	$1.8x10^6$	<10	<10	<10	<10	<10	<10	$1.2x10^4$	$1.2x10^2$	$6.3x10^3$	$5.6x10^2$	$4.5x10^3$	$3.8x10^3$
Wheat flour	$3.1x10^5$	$1.1x10^4$	$1.9x10^4$	<10	<10	<10	<10	<10	<10	$1.9x10^2$	$5.8x10^3$	$1.8x10^2$	<10	<10	<10

Appendix XIII (continued)

Cereal base/ storage time	Total colony count			Coliforms			Yeasts and moulds			Aerobic spore-formers: Mesophiles			Aerobic spore-formers: Thermophiles		
	M[a]	D[b]	Y[c]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
12 Month															
Trial 1st															
Supplier A															
Porridge oats	1.3×10^6	5.0×10^4	2.3×10^3	<10	<10	<10	<10	<10	<10	1.4×10^2	4.2×10^2	1.1×10^2	1.1×10^2	1.5×10^2	1.1×10^2
Oats flour	5.9×10^5	2.9×10^4	1.7×10^3	<10	<10	<10	<10	<10	<10	1.3×10^2	1.1×10^2	1.2×10^2	1.3×10^2	<10	<10
Burghol	1.2×10^6	1.1×10^4	1.4×10^4	<10	<10	<10	<10	<10	<10	5.2×10^3	3.5×10^3	4.0×10^3	8.4×10^3	5.9×10^3	9.0×10^3
Wheat flour	5.1×10^5	1.2×10^4	1.3×10^4	<10	<10	<10	<10	<10	<10	1.3×10^3	3.2×10^3	4.3×10^3	<10	<10	1.7×10^2
Supplier B															
Porridge oats	1.8×10^5	5.9×10^4	2.4×10^4	<10	<10	<10	<10	<10	<10	2.5×10^2	4.7×10^2	2.0×10^2	4.9×10^2	3.6×10^2	1.1×10^2
Oats flour	2.7×10^6	2.4×10^3	2.6×10^3	<10	<10	<10	<10	<10	<10	<10	1.5×10^2	2.3×10^2	1.5×10^2	1.1×10^2	1.4×10^2
Burghol	2.8×10^6	5.1×10^3	3.3×10^4	<10	<10	<10	<10	<10	<10	5.3×10^3	4.6×10^3	5.8×10^3	4.9×10^3	3.8×10^3	2.5×10^3
Wheat flour	3.4×10^5	2.9×10^4	5.7×10^3	<10	<10	<10	<10	<10	<10	<10	2.1×10^2	5.0×10^3	<10	1.7×10^2	1.2×10^2
Trial 2nd															
Supplier A															
Porridge oats	1.6×10^6	3.1×10^3	1.7×10^4	<10	<10	<10	<10	<10	<10	1.8×10^2	9.7×10^3	2.1×10^2	1.4×10^2	2.4×10^2	1.5×10^2
Oats flour	1.9×10^6	1.5×10^5	1.3×10^3	<10	<10	<10	<10	<10	<10	1.1×10^2	4.3×10^2	2.0×10^2	1.0×10^2	1.1×10^2	2.1×10^2
Burghol	1.3×10^6	4.8×10^4	1.5×10^4	<10	<10	<10	<10	<10	<10	4.4×10^3	2.7×10^3	4.1×10^3	6.5×10^3	7.4×10^3	7.8×10^3
Wheat flour	1.9×10^4	8.1×10^4	5.6×10^3	<10	<10	<10	<10	<10	<10	2.0×10^3	4.6×10^3	2.3×10^3	<10	1.1×10^2	1.2×10^2
Supplier B															
Porridge oats	3.0×10^5	7.9×10^4	3.4×10^4	<10	<10	<10	<10	<10	<10	4.0×10^2	1.8×10^2	3.7×10^3	4.9×10^3	1.7×10^2	1.6×10^2
Oats flour	2.3×10^6	1.6×10^4	1.6×10^3	<10	<10	<10	<10	<10	<10	5.2×10^2	1.3×10^2	2.3×10^2	4.6×10^3	<10	1.5×10^2
Burghol	2.5×10^6	1.4×10^4	1.1×10^4	<10	<10	<10	<10	<10	<10	6.2×10^3	5.5×10^2	2.9×10^3	5.1×10^3	4.3×10^3	2.4×10^2
Wheat flour	3.8×10^5	1.8×10^4	7.4×10^3	<10	<10	<10	<10	<10	<10	<10	3.3×10^2	3.6×10^3	<10	1.8×10^2	3.0×10^2

[a] 'Milk'. [b] GDL. [c] Yoghurt. [d] No growth at 10^{-1} dilution. Results are average of single sample plated in duplicate.

Appendix XIV Enumeration of starter organisms (cfu g^{-1}) of Kishk made from different cereals and yoghurt base.

Kishk sample	*Str. thermophilus*			*Lb. delbrueckii* subsp. *bulgaricus*		
	Fresh	6 month	12 month	Fresh	6 month	12 month
Trial 1st						
Supplier A						
Porridge oats	1.5×10^3	1.3×10^3	<10	1.5×10^3	<10	<10
Oats flour	2.2×10^3	<10[a]	<10	1.3×10^3	<10	<10
Burghol	9.5×10^5	2.1×10^4	1.2×10^4	5.3×10^3	2.7×10^3	2.4×10^3
Wheat flour	1.2×10^4	2.3×10^4	1.1×10^4	1.2×10^3	<10	<10
Supplier B						
Porridge oats	1.3×10^4	1.2×10^3	<10	<10	<10	<10
Oats flour	1.8×10^3	1.5×10^3	<10	<10	<10	<10
Burghol	2.2×10^6	3.4×10^5	3.4×10^3	7.9×10^5	1.6×10^5	1.9×10^3
Wheat flour	3.3×10^3	<10	6.8×10^2	6.7×10^3	<10	<10
Trial 2nd						
Supplier A						
Porridge oats	1.4×10^3	1.1×10^3	<10	2.1×10^3	<10	<10
Oats flour	1.2×10^3	<10	<10	2.3×10^3	<10	<10
Burghol	4.2×10^5	<10	1.3×10^4	5.0×10^3	2.8×10^3	<10
Wheat flour	1.5×10^4	1.7×10^3	4.8×10^3	1.3×10^3	1.0×10^3	<10
Supplier B						
Porridge oats	1.1×10^4	2.1×10^4	<10	2.2×10^3	<10	<10
Oats flour	1.1×10^3	1.3×10^3	<10	<10	<10	<10
Burghol	2.7×10^6	1.5×10^6	2.6×10^3	1.0×10^6	8.7×10^5	1.5×10^3
Wheat flour	1.2×10^3	<10	9.4×10^2	4.9×10^3	<10	<10

[a] No growth at 10^{-1} dilution. Results are average of single sample plated in duplicate.

Appendix XV Chemical composition (g 100 g^{-1})[a] of Kishk made from different wheat products, acidulants and 'milk'.

Cereal base	Moisture			Fat			Protein			Carbohydrate			Ash		
	M[b]	D[c]	Y[d]	M	D	Y	M	D	Y	M	D	Y	M	D	Y
Supplier A															
Burghol	12.74	12.65	10.76	6.02	5.16	6.52	21.86	20.16	22.18	68.87	69.20	65.21	3.25	5.48	6.09
Burghol flour	12.15	12.70	11.75	6.16	5.37	6.28	22.30	20.69	22.81	68.27	68.49	64.81	3.27	5.45	6.10
Wheat flour	12.84	12.70	12.06	5.70	3.90	6.66	20.71	19.25	21.79	70.49	71.46	65.38	3.10	5.39	6.17
Supplier B															
Burghol	12.89	11.46	12.15	6.19	5.07	6.59	21.82	19.52	22.40	68.63	69.89	64.87	3.36	5.52	6.14
Burghol flour	12.72	12.65	10.54	5.97	5.32	6.65	21.60	19.99	22.23	69.08	69.21	64.85	3.35	5.48	6.27
Wheat flour	11.44	12.75	12.73	5.25	4.28	6.53	20.17	19.38	21.35	71.45	71.06	65.58	3.13	5.28	6.54

[a] Data was calculated on dry matter basis.
[b] 'Milk'. [c] GDL. [d] Yoghurt.
Results are average of two determinations performed on each sample.

Appendix XVI Proximal α-amylase (Units g^{-1}), total starch content (g 100 g^{-1} DMB) and soluble protein (g 100 g^{-1}) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.

Time (h)	Supplier A				Supplier B			
	Burghol		Wheat flour		Burghol		wheat flour	
	A[a]	B[b]	A	B	A	B	A	B
α-amylase								
0	0.025	0.025	0.028	0.028	0.017	0.017	0.026	0.026
48	0.027	0.025	0.068	0.033	0.025	0.017	0.061	0.032
96	0.068	0.075	0.030	0.039	0.035	0.045	0.041	0.053
144	0.154	0.184	0.004	0.023	0.170	0.175	0.004	0.014
Starch								
0	31.78	32.38	34.20	34.51	29.42	31.94	35.23	36.88
48	25.27	24.67	24.99	25.98	24.69	24.48	27.67	26.70
96	17.77	17.82	18.36	14.92	18.60	16.42	16.91	15.41
144	13.47	12.20	14.99	12.11	10.97	11.58	13.62	12.96
Soluble protein								
0	0.22	0.22[c]	0.27	0.26[c]	0.20	0.20[c]	0.28	0.28[c]
48	0.39	0.32	0.63	0.48	0.37	0.31	0.61	0.49
96	0.39	0.37	1.01	0.87	0.39	0.37	1.01	0.94
144	0.41	0.53	1.27	1.06	0.40	0.49	1.43	1.10

[a] Yoghurt. [b] Yoghurt + sodium azide. [c] Yoghurt + antimicrobial tablets.

Appendix XVII Microbial count (cfu g^{-1}) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.

Kishk sample	Total colony count				Coliforms				Yeasts and moulds			
	0 h	48 h	96 h	144 h	0 h	48 h	96 h	144 h	0 h	48 h	96 h	144 h
Supplier A												
Burghol	$1.7x10^4$	$7.4x10^4$	$2.1x10^7$	$1.7x10^9$	<10[b]	<10	<10	<10	<10	$1.2x10^2$	*	$1.5x10^5$
Burghol + sodium azide	$1.1x10^3$	$1.0x10^3$	$6.4x10^3$	$3.5x10^3$	<10	<10	<10	<10	<10	<10	<10	<10
Wheat flour	$2.3x10^4$	$1.2x10^5$	$2.9x10^7$	$7.7x10^8$	<10	<10	<10	<10	<10	$1.6x10^2$	$1.5x10^4$	$2.5x10^5$
Wheat flour + sodium azide	$8.3x10^2$	$6.8x10^2$	$4.3x10^3$	$4.5x10^3$	<10	<10	<10	<10	<10	<10	<10	<10
Supplier B												
Burghol	*[a]	$1.3x10^4$	$1.8x10^7$	$8.8x10^8$	<10	<10	<10	<10	<10	$1.5x10^2$	$2.9x10^4$	$3.4x10^5$
Burghol + sodium azide	$1.8x10^2$	$8.0x10^2$	$4.0x10^3$	$3.8x10^3$	<10	<10	<10	<10	<10	<10	<10	<10
Wheat flour	$1.3x10^4$	$5.4x10^4$	$9.1x10^7$	$1.1x10^9$	<10	<10	<10	<10	$1.2x10^2$	$4.9x10^2$	$2.4x10^4$	$2.2x10^5$
Wheat flour + sodium azide	$1.8x10^2$	$1.2x10^2$	$4.0x10^2$	$3.3x10^2$	<10	<10	<10	<10	<10	<10	<10	<10

[a] No growth at 10^{-3} dilution. [b] No growth at 10^{-1} dilution.

Results are average of single sample plated in duplicate.

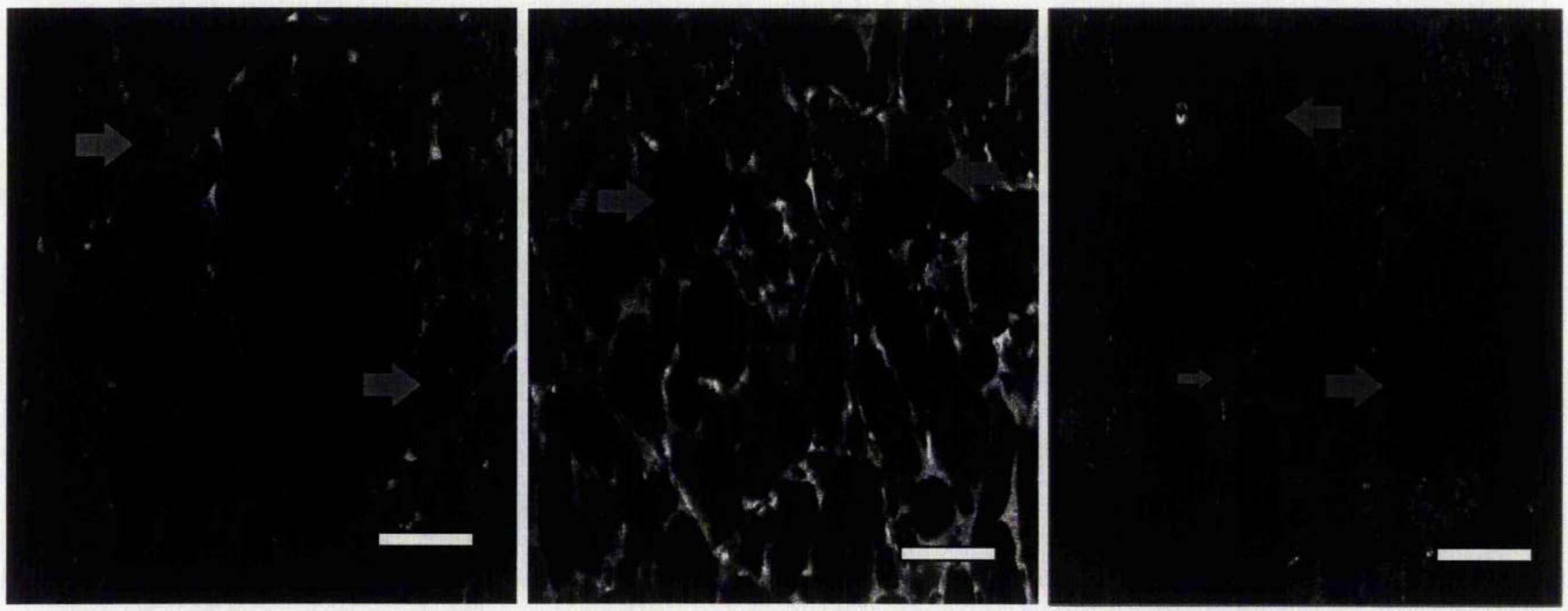
Appendix XVIII **Enumeration of starter organisms (cfu g^{-1}) of yoghurt/Burghol or wheat flour mixture during the secondary fermentation period.**

Kishk sample	*Str. thermophilus*				*Lb. delbrueckii* subsp. *bulgaricus*			
	0 h	48 h	96 h	144 h	0 h	48 h	96 h	144 h
Supplier A								
Burghol	$1.7x10^{10}$	$4.0x10^{10}$	$6.6x10^{11}$	$5.6x10^{11}$	*[c]	$1.5x10^{8}$	$2.3x10^{9}$	$2.0x10^{9}$
Burghol + sodium azide	<10[a]	<10	<10	<10	<10	<10	<10	<10
Wheat flour	*[b]	$1.5x10^{10}$	$1.3x10^{11}$	$2.4x10^{13}$	*[c]	$2.1x10^{8}$	$2.7x10^{9}$	$5.2x10^{11}$
Wheat flour + sodium azide	<10	<10	<10	<10	<10	<10	<10	<10
Supplier B								
Burghol	*[b]	*[b]	$1.2x10^{11}$	$1.3x10^{11}$	$2.5x10^{8}$	$1.1x10^{9}$	$1.3x10^{11}$	$1.2x10^{11}$
Burghol + sodium azide	<10	<10	<10	<10	<10	<10	<10	<10
Wheat flour	$5.2x10^{10}$	$2.7x10^{11}$	$2.2x10^{12}$	$1.2x10^{13}$	$6.1x10^{8}$	$2.5x10^{9}$	$2.5x10^{11}$	$7.3x10^{11}$
Wheat flour + sodium azide	<10	<10	<10	<10	<10	<10	<10	<10

[a] No growth at 10^{-1} dilution. [b] No growth at 10^{-9} dilution. [c] No growth at 10^{-7} dilution.

Results are average of single sample plated in duplicate.

A B C



Arrows (large) showing starch granules and (small) casein aggregates.

Appendix XIX The microstructure (144 h) of yoghurt/Burghol mixture plus the addition of sodium azide (A); whey/Burghol mixture plus the addition of antimicrobial tablets (B); yoghurt/wheat flour mixture plus the addition of sodium azide (C). Bar size = 10 μm.