



**Effect of Adding Different Levels of Gum-Arabic
on Physicochemical, Microbiological and Sensory
Characteristics of Sudanese White Cheese during Storage**

تأثير إضافة مستويات مختلفة من الصمغ العربي على الصفات
الكيميائية الفيزيائية والميكروبيولوجية والحسية
للجبنه البيضاء السودانية خلال فترة التخزين

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DEDICATION

To my father and mother,
To my beloved wife,
To my sons Moueiz, Abdel Wahab, Yousif
and to single daughter Hana,
To my dear brothers and sisters.

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ABSTRACT

This study was carried out at the laboratory of Dairy Science and Technology Department, College of Animal Production Science and Technology at Sudan University of Science and Technology during the period from September 2014 to January 2015, to determine the effect of different levels of Gum Arabic on the physicochemical characteristics, microbiology quality and sensory properties during storage. Three hundred and fifty liters (350 liters) of standardized milk were used for the production of Sudanese white cheese with different levels of Gum Arabic (0.5, 0.75%).

Seven treatments were carried out as follows: first treatment is the control in which cheese milk had no additive (3% of fat). In the second and third treatments with 3% of fat, fourth and fifth treatments with 25% of fat and sixth and seventh treatments with 2% of fat for each of the above treatments 0.5 and 0.75% of Gum Arabic were added respectively, to cheese milk before pasteurization (at 72°C) for one minute and then manufactured into a Sudanese white cheese and stored at refrigerator (4°C) for 120 days and examined for the physicochemical, microbiological and organoleptic quality at day 0, 30, 60, 90 and 120 intervals.

The results indicated that total solids, fat, volatile fatty acids and ash content increased significantly ($P<0.05$) with increase levels of Gum Arabic, while protein and pH decreased significantly ($P<0.05$) with the levels of Gum Arabic.

There were significant effect ($P<0.05$) of the levels of Gum Arabic on total bacterial count, coliforms bacterial count, lactic acid bacterial count and yeasts and moulds counts. The total bacterial count, coliforms and yeasts and moulds decreased with the levels of Gum Arabic, while lactic acid bacteria increased.

The organoleptic of the cheese revealed that there were significant effect ($P<0.05$) of Gum Arabic on colour, flavour and texture, while there were no

significant effect on saltiness, the results also indicated that there were significant effect ($P < 0.05$) of the storage period on total solids, protein, ash, pH, volatile fatty acids and ash content. Crude protein, ash and total solids content increased with storage period, while pH, volatile fatty acids and fat increased with the storage period in all treatments.

The total bacterial counts decreased significantly ($P < 0.05$) with storage period from day zero up to day 90 and then slightly increased. Coliforms increased from day zero up to day 90 of the storage and did not detected at day 120, lactic acid bacteria decreased from day zero up to day 60 then increased at day 90 thereafter wards decreased at day 120, while yeasts and moulds increased at day 30 of the storage time then afterwards decreased up to day 90 and completely disappeared at day 120 of the storage time.

Flavour, texture and saltiness decreased significantly ($P < 0.05$) with the storage period, while colour increased significantly ($P < 0.05$) at day 60 and then gradually decreased up to day 120 of the storage period.

The best scores for colour were recorded at day 60, while the best flavour recorded at day zero. Saltiness increased at day zero and then decreased afterwards up to the end of storage period.

The present study concluded that significant effect was found on the physicochemical, microbiological and sensory characteristics of the Sudanese white cheese during the storage as the result of using Gum Arabic.

المستخلص

أجريت هذه الدراسة بمعمل قسم تكنولوجيا الالبان بكلية علوم وتكنولوجيا الإنتاج الحيواني بجامعة السودان للعلوم والتكنولوجيا في الفترة من سبتمبر 2014 إلى يناير 2015م بهدف تقييم تأثير المستويات المختلفة من الصمغ العربي على الصفات الفيزيوكيميائية، الجودة الميكروبيولوجية والتقييم الحسي للجبن البيضاء السودانية، أثناء فترة التخزين في هذه التجربة تم استخدام ثلاث مائة وخمسون لتر (350 لتر) من لبن معدل في نسبة الدهن (2، 2.5 و 3%) وصمغ عربي بمستوى (0.5 و 0.75%).

أجريت سبعة معاملات، المعاملة الأولى صنعت فيها الجبنة دون إضافة الصمغ العربي، في المعاملة الثانية والثالثة والتي بها نسبة دهن 3% تم إضافة 0.5 و 0.75% على التوالي لكل معاملة، في الرابعة والخامسة والتي بها نسبة دهن لبن 2.5% تم إضافة 0.5 و 0.75% صمغ عربي على التوالي لكل معاملة، في السادسة والسابعة والتي بها نسبة دهن لبن 2% تم إضافة 0.5 و 0.75% صمغ عربي على التوالي لكل معاملة ثم بسترة اللبن لدرجة حراري 72°م لمدة دقيقة وبرد لدرجة حرارة 42°م بعدها تم اضافة بودرة المنفحة (5جر ام لكل 50 لتر لبن) عند درجة حرارة 40 درجة مئوية حتي تم تصنيع العينات من الجبن وتم تخزينها بالثلاجة على درجة حرارة (42°م) لمدة 120 يوم وتم إجراء التحاليل في اليوم (0، 30، 60، 90 و 120 على التوالي).

أظهرت الدراسة بأن الجوامد الصلبة والدهن والأحماض الدهنية الطيارة والرماد تزيد معنوياً ($P < 0.05$) بإضافة مستويات مختلفة من الصمغ العربي أما البروتين والأس الهيدروجيني تتناقص معنوياً بزيادة نسبة الصمغ العربي. كما كان هنالك تأثير معنوي ($P < 0.05$) لمستويات الصمغ العربي المختلفة على كل من العدد الكلي للبكتريا وبكتريا حامض للأكتيك وبكتريا القولون (الكولي فورم بكتريا) بجانب الخمائر والفطريات. حيث تناقص العدد الكلي للبكتريا وكذلك الميكروبات الأخرى بمستويات الصمغ العربي.

أثرت نسبة الصمغ العربي معنيوا ($P < 0.05$) على كل من اللون والرائحة والقوام بينما لم تتأثر الملوحة. سجلت الجبنة المصنعة من اللبن غير المضاف إليه الصمغ العربي أعلى معدل بالنسبة للون والرائحة والقوام والملوحة. بينما سجلت الجبنة المصنعة من اللبن المضاف إليه 0.5% صمغ عربي أدنى معدل في القوام (3.98 ± 1.92). أوضحت الدراسة أن فترة التخزين قد أثرت معنوياً على كل من البروتين والرماد والجوامد الصلبة حيث إزدادت خلال فترة التخزين بينما تناقصت في كل من اللأس الهيدروجيني والأحماض الدهنية الطيارة والدهن.

أوضحت الدراسة تناقص العدد الكلي للبكتريا معنوياً ($P < 0.05$) بتقدم فترة التخزين حتى نهايتها وكذلك اختفت بكتريا القولون في اليوم 120 لفة التخزين وإزدادت بكتريا (اللاكتيك) حامض اللاكتيك في اليوم 90 لفترة التخزين أما الخمائر والفطريات وتزايدت معنوياً ($P < 0.05$) في اليوم 30 ثم تناقصت بتقدم فترة التخزين حتى إنعدمت كلياً عند اليوم 120 من فترة التخزين، تأثرت الخواص معنوياً ($P < 0.05$) بتقدم فترة التخزين حيث أظهرت النتائج أن أفضل معدل للون والرائحة والقوام تم تسجيلها في اليوم الأول من فترة التخزين بينما أقل معدل للملوحة تم رصدها في اليوم 120 من فترة التخزين.

خلصت نتائج التجربة وجود فروقات معنوية في كل من الخواص الكيميائية الفيزيائية والميكروبيولوجية والحسية للجبنة البيضاء السودانية خلال فترة التخزين عند إستخدام الصمغ العربي.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Various kinds of cheese are the most popular cheese among consumers in Sudan. They are made on small holder's dairy farms from cow, sheep and goat milk and consumed after maturation or in fresh form, white fresh cheese from many areas of Sudan are economically important for these areas. The traditional methods of production involve renneting, curd formation, fermentation and final preparation for market (Ibrahim, 2003). Cheese plays an important role in the Sudanese diet and many people eat a certain amount of cheese with at least twice per week in one of their meals, most of the cheese is consumed either directly or with bread (Dhuol and Hamid, 2013).

Sudanese white cheese (Gibna Bayda) is most common cheese in the Sudan. It has a strong odour and taste. It is made from raw or pasteurized whole milk, skim milk or reconstituted milk, depending on natural lactic acid bacteria, no starter is used and coagulated by rennet enzyme; it is saled by adding sodium chloride direly to milk and packed in tin cans (Abdel-Razig, 1996).

According to Lakovchenko and Aresenva (2016) cheese is highly concentrated product which is rich in protein and minerals such as calcium and phosphorus and essential amino acid, therefore, it is an important food in the diet.

In the past 20 year, the popularity and commercialization of food that could be beneficial to human health have significantly increased around the

world. Milk products including cheese and especially those with the lower fat content; represent a good base for the development of new products with functional properties. The most popular functional dairy products are produced with the addition of Gum Arabic (Kosikowski, 1982).

An increased awareness of the positive impact of healthful food is leading many people to change their eating habits and more carefully consider what they consume. Cheese is known as a complete nutritious food product and excellent source of many key nutrients, suitable for many ages. It is rich in protein and minerals such as calcium, there are different types of cheese: soft cheese, semi hard and hard cheese, the difference in these types mainly due to water content or water activity and the methods and technology for cheese making (Pantaleao *et al.*, 1990).

Consumer awareness of dietary fat has increased and the demand for low-fat foods including cheese has grown substantially. However, growth in the low-fat cheese market has been slower than would be anticipated on the basis of increased consumer awareness of dietary fat intake (Banks, 2004).

A low-fat diet is one that restricts fat and often saturated fat and cholesterol as well, low fat diets are intended to reduce diseases such as heart disease and obesity. Reducing fat in the diet can make it easier to cut calories. Fat provides nine calories per gram, while carbohydrates and protein each provide four calories per gram, so choosing low-fat foods makes it possible to eat a larger volume of food for the same number of calories (Bazzano, 2014).

1.2 Research problems

Removal of fat from cheese cause textural, functional and sensory defects such as rubbery texture, lack of flavour, bitterness, off-flavour, poor meltability and undesirable colour. Therefore several strategies have been

proposed in order to provide the consumer with valuable sources of nutrients; However, Gum Arabic can be used to upgrade the nutritional value of the white cheese and to improve the quality of the cheese due to its high content of calcium, potassium and magnesium.

1.3 Research objectives

1. To study the physicochemical, microbiological and sensory characteristics of Sudanese white cheese as affected by the different levels of Gum Arabic during storage.
2. To determine the effects of different fat levels on the physico-chemical microbiological and sensory characteristics of Sudanese white cheese.

CHAPTER TWO

LITERATURE REVIEW

2.1 Cheese

Cheese is an excellent source of protein and minerals such as calcium and phosphorus essential amino acids. Therefore it is an important food product for both young and old people (Krupa *et al.*, 2011). While Lakovechenko, and Arsenva (2016) mentioned that cheese is highly concentrated product, which is rich in protein and minerals such as calcium and phosphorus, essential amino acids, therefore it is an important food in the diet. Cheese is a product that made from the curd obtained from milk by coagulating the casein with the help of rennet or similar enzymes in the presence of lactic acid microorganism (Ramakant, 2006).

Cheese can be defined as the fresh or ripened product obtained after coagulation and whey separation of milk, butter milk or a mixture of these products, Law (1999); Fox *et al.* (2000) and Andrew (2010) defined cheese as a nutritious food made mostly from the milk of cow's, buffaloes and sheep or goats are an important component of U.K. diet.

Sudanese white cheese is the term that generally refers to cheese whose fat content is lower than its corresponding full fat variety. Moreover, Sudanese white cheese is usually characterized as having poor body, flavor and functional properties because of high moisture and salt (Mistry, 2001).

2.1.1 Classification of cheese

There are several hundred varieties of cheese which may be divided into different class or groups. Different methods are used for classification such as hardness, moisture content, organism used for ripening and

conditions or products from which cheese is made (Petersen, 1950). Traditional classification schemes have been based principally on moisture content, such as hard, semi-hard or soft, but are a widely used basic for classification and manufacturing protocols (Fox *et al.*, 2000). Walter and Hargrove (1972) classified cheese on the basis of manufacturing technique, suggested that they are only 18 distinct types of natural cheese, which they grouped into 8 families under the heading very hard, semi-soft and soft:

1. Very hard (grating):

- Ripened by bacteria (e.g. Parmesan).

2. Hard:

- Ripened by bacteria, without eyes (e.g. Cheddar).
- Ripened by bacteria, with eyes (e.g. Emmental).

3. Semi-soft:

- Ripened principally by bacteria (e.g. Gouda).
- Ripened by bacteria on surface microorganisms (e.g. Limburger).

4. Soft:

- Ripened (e.g. Brie).
- Unripened (e.g. cottage).

In view of the schemes proposal by the FAO/WHO (1978), some existing cheese regulation, a generalized method for the classification of cheese was based on methods of manufacture and chemical analysis. Fox *et al.* (1993) proposal a number of meaningful "super families" into which all cheese would be grouped based on the method of milk coagulation:

1. Rennet – coagulation cheese (most major international cheese varieties).
2. Acid coagulated.

3. Heat acid coagulated.
4. Concentration/crystallization.

All ripened cheeses are coagulated by rennet (70% of total world production). Acid-curd cheeses are the next most important group. Coagulation by a combination of heat and acid is used for a few minor varieties, including Ricotta, concentration/crystallization is used in Norway to produce "whey cheese" (e.g. mysost). There is a great diversity of rennet-coagulated cheese and therefore, they must be classified (Fox, 1993).

2.2 Sudanese dairy products

Sudanese traditional fermented foods represent the main source of nutrition for rural and urban communities. Dairy product participated in enhancement of the economy, finance and business of local societies (Salih *et al.*, 2011). The various sources of fresh milk in Sudan shaped the different traditional dairy products. Dirar (1993) divided the Sudanese fermented dairy product into two major groups; the truly indigenous which include Rob, Gariss, Biruni and mish and the Quasi-indigenous which include Zabadi and Gibna bayda. Methods of preparation are different slightly from one part of the country to another. The most important traditional product are Rob (fermented milk product mainly of cow's), Zabadi (local name of yoghurt), Gariss (fermented camel's milk product) Gibna Bayda (white cheese), Gibna Mudaffara (white pickled cheese) and Mish (fermented milk product with species (Dirar, 1993; Abdel Gadir *et al.*, 1998).

2.2.1 Rob

Rob is produced in rural areas mainly on household levels. It is popularly known way for surplus milk preservation. Rob is made from

fermentation of cow, sheep and goat's milk. The bulk is made from cow's milk while a smaller proportion is prepared from either goats or sheep's milk or mixture of these two milks (Abdel Gadir *et al.*, 1998; Dirar, 1993). In urban, Rob is usually refrigerated and consumed with sugar as a desert or eats with wheat bread, sometimes it is fed to babies and often turned into sauce for Aceda (porridge) or given to young animals as milk replacer (Dirar, 1993). Most of the developing countries started to search in their indigenous homemade, yoghurt for effective anti-bacterial agents against enteric pathogens (Salih *et al.*, 2011; Osuntoki *et al.*, 2008; Yesillik *et al.*, 2011).

2.2.2 Gibna

White soft cheese is one of the most widespread type of cheese produced in Sudan, locally known as Gibna Bayda it is a pickled soft cheese that is stored under anaerobic conditions in air tight containers filled with whey (Kur, 1984). The highest production is during the rainy season (Hamid and El Owni, 2007). They are varying in composition, texture, colour, taste and flavour. The variation is due to composition of milk, methods of production, microbial flora, type of package, microbial activity during ripening and ripening conditions. Cheese manufacturing is influenced by product composition, processing, packaging and storage conditions, control of temperature and humidity and transportation are dynamic aspect of health hazards (Nour El-Diam and El Zubeir, 2006).

2.2.3 Sudanese white cheese

The real beginning of cheese-making is unrecorded in history. However, it must have occurred within few centuries after the domestication of the cows and other mammals about 8000 B.C. (John, 1975). While

in Sudan cheese production has been started in the early eighteenth century by the Greek families who migrated to Sudan. They settled mainly at El Dueim in the White Nile State (El Tayeb, 1986). The major types of the cheese produced in the Sudan are Gibna Bayda and Gibna Mudaffra (El-Sheikh, 1997; Hamid and El Owni, 2007).

Sudanese white cheese (Gibna Bayda) is unique in containing high concentrations of salt (Sodium chloride) which is added to the milk before processing. High salting preserve cheese from rapid deterioration before ripens (Taormina, 2010; Osman, 1987).

2.2.4 Gibna mudaffara

Gibna Muddafa is similar to Gibna Bayda but high percentage of salt is added to milk. Rennet or rennet extract is added to obtain a firm coagulum which develops in four to six hours. Ripening takes place while the cheese is submerged in whey. The purpose of coagulant is the conversion of liquid milk into gel catalyzed by different proteases (Green, 1984). Gibna Mudaffara preserved for long time by immersion in the whey. For marketing it is packed in tins or other suitable sealed containers (Dirar, 1993; Abdel Gadir *et al.*, 1998).

2.2.5 Mish

Mish is famous fermented milk product recently introduced from Egypt (El Mardi, 1988). Mish is produced by biology milk, cooling and inoculation with small quantity of the previous batch or rob. After souring, seeds of black cumin (*Nigella sativa*), seeds of fenugreek (*Trigonella foenum graecum*) and perhaps a few pods of green or red pepper are added. The product is fermented for 2 or more days before consumption. In modern dairy industry, it is made from whole cow's or skim milk by adding

starter culture, and after curdling spices such as black cumin, fenugreek, garlic and sometimes hot or green pepper are added, then is packaged and left for 24 hours to ripen and develop a curd (Ahmed, 2007; Dirar, 1993).

2.2.6 Gariss

Garris is unique Sudanese traditionally fermented camel's milk product. It made a semi-continuous fermentation process. The word Gariss means pinching or stinging, denoting a high degree of sourness (Dirar, 1993).

2.2.7 Biruni

Biruni is similar to mish. Its manufacturing was limited to Nuba Mountains area but recently spread into the area inhabited by pastoralists who named it Laban-gadim (aged milk). Biruni is stored at least for one year and may extend to more than ten years, the main purpose of making Biruni secret at it consumed years after fermentation (Dirar, 1993).

2.2.8 Samin (Ghee)

Ghee, widely considered as the Indian name for clarified butterfat, usually prepared from cow milk or buffalo milk at combination thereof (Kumar *et al.*, 2010). Also in many African countries is produced from butter (Sserunjogi *et al.*, 1998).

The process involves a gradual heating of Butter, during which water is driven off and protein is dehydrated and precipitated. Then oil is extracted in a closed tight container, Samin is home-made product and mainly add to Rob sauce and for bakery.

2.2.9 Romano cheese

It is hard type of cheese and probably derived from Italian cheese which is Italian types of cheese. Little quantities of this type of cheese are produced at Kazagil, Kordofan region (Khateeb, 1977).

2.2.10 Mozzarella cheese

Mozzarella cheese has become one of the most popular cheese varieties in the world because of its primary use in Pizza preparation. Its usage is expected to grow as global interest due to the ever increasing demand for pizza and other foods that use mozzarella. Buffalo milk is preferred for mozzarella due to high fat, vitamin (A), protein and low cholesterol (Zicarelli, 2004). Differences in fat level and hence protein to fat ratio, that occur in milks have market influence on composition, yield, archeology flavour and sensory attributes of cheese (Guinee, 2004).

2.3 History of Sudanese dairy product

The introduction of fermented milk products to human civilization date back many thousands of years (Campbell-Platt, 1994). They may originated in the Middle East and date back long before the Phoenician era. It was proved that laban rayeb and laban khad (traditional Egyptian fermented milk products) were consumed as early as 7000 before Christ (Kosikowski and Ministry, 1997).

The Sudanese history of using milk dated back to 5000 years ago. Strong evidence proved that people of Meroe Kingdom, (690 Bc-D 323) may know how to ferment cow milk (Abdel Gadir *et al.*, 1998). Milk fermentations provide away for long-term preservation, enhance the nutritional value, improve the appearance of various products, give the

desirable taste, prevent the spoilage and reduce the effort and time required for cooking (Tamime, 2002; Motarjemi, 2002; Floros *et al.*, 2010). The souring of milk into a product or into certain dairy product is a widespread practice. These products are art specific of certain country whereas others are confined to specific geographical locals (Abdel Gadir *et al.*, 1998), Moreover, more than half of the quantity of milk in Sudan is processed into some fermented dairy products such as rob and mish. In addition, there are two famous products namely Gibna-Bayda and Zabadi (Dirar, 1993).

Mohamed (1987) reported that the existing method of making Sudanese white cheese has been introduced by the Greek family who settled in Eldueim in 1980 and they later 1992 established the first cheese plant intended for commercial production. Al-Awad (1981) suggested that white cheese was introduced into Sudan from Egypt during colonial times (1898-1956) and that the Sudanese merchants later look up the manufacturing task and adding their own flavour to the product. It was also believed that the technology of cheese making has been introduced to Sudan either from Egypt or Mediterranean countries such as Greece (Ibrahim, 1970 and Ali, 1987).

2.4 Sudanese white cheese making

The real beginning of Sudanese white cheese making is unrecorded in the history. However, Mistry and Anderson (1993) reported that in the past 15 years the commercialization of Sudanese white cheese production around the world has significantly accelerated. Even though the concept of Sudanese white cheese manufacture is not a new idea precise, the emphasis on control of caloric intake, especially in develop countries, in the past 20

years has largely been responsible for the growth in Sudanese white cheese markets. In the United State for example, the recommended caloric intake from fat is not more than 30%. Guidelines for the reduction in consumption of fat and, especially consumption of low-fat products exist in other countries as well (Holund and Truswell, 1999).

Sudanese white cheese involves three broad, a processing techniques, starter culture selection and use of additives such as stabilizer and fat replacers. Research on the development of processing techniques for Sudanese white cheese commenced over 50 years ago, the reason for producing such cheeses ranged from increasing yield to fat reduction for nutrition purpose (Mistry and Anderson, 1993).

Madadlou *et al.* (2005) reported that since Sudanese white cheese have a more continuous protein network with few interruptions from fat, the extent of proteolysis becomes important for developing the desired cheese texture during storage. Doubling the rennet level used in making low-fat Iranian white cheese made the cheese softer, more meltable and improved the sensory impression of texture (Romeih, 2002).

Using a more proteolytic coagulant increased primary proteolysis during storage in reduced fat mozzarella cheese, but no improvement was observed in firmness or melting properties (Sheehan *et al.*, 2004).

In contrast, storage at a higher temperature increased the rate of proteolysis and reduced firmness and increased heat induced flow ability. It has generally been observed that lower flavour scores are obtained with virtually all varieties of cheese when fat content is lowered more than 50%. For example, fat content in the Greek sheep's milk Kefalograviera could be reduced by have with no significant change in flavour scores, but a 75% reduction produced a cheese with lower flavour scores (Katsiari and

Voutsinas, 1994). Adding enzymes to hydrolyze protein or lipids will increase the formation of amino acids and fatty acids, although this will necessarily produce improved flavour, Michaelidou *et al.* (2003) observed that adding freeze-shocked lactobacillus was better at improving the flavour of low-fat Edam cheese than adding a protease/lipase mixture.

2.4.1 Chemical composition of Sudanese white cheese

The term Sudanese white cheese generally refers to cheeses whose fat content is lower than its corresponding full-fat variety. As a result, there is a major shift in the compositional balance of various components of cheese compared with its full-fat counterpart, specially, as the fat content of cheese is lowered, moisture in non-fat substance of cheese is generally equal to that in full-fat cheese (Mistry and Anderson, 1993) (Table 1). Consequently, the content of salt in the moisture phase of cheese is lowered. This change in the micro environment is largely responsible for the shift in the functional and sensory characteristics of the cheese (Banks Hunters and Banks *et al.*, 1993; Bryant and Ustunol, 1995) as well as in its microbiology and biochemistry (Nauth and Ruffie, 1995). The greater the reduction in fat, the more severe these shift are Ripened, Sudanese white cheeses have flavour that is a typical for the variety. In low-fat cheddar cheese, the lack of an imbalance of flavour has been associated with lowered levels of fatty acids such as botanic and hexanoic acids and methyl Ketones (Bank, *et al.*, 1989). The difference in the rate of release of flavour compounds from cheese during chewing is also a factor in flavour perception (Delahunty *et al.*, 1996). For example, 2 butanone and 2 heptanone are released at a higher rate in reduced fat cheese (Delahunty *et al.*, 1996). Therefore, the total flavour perception is different. Another factor in the lack of flavour is interaction between starter bacteria cells and milk fat globules.

Laloy, *et al.* (1996) demonstrated that fat free and 50% reduced fat cheddar cheeses had fewer starter cells than full-fat cheeses; they suggested that the bacterial population in curd was directly related to the fat content of cheese.

Bitterness develops early in the aging process and is common defect in mature Sudanese white cheeses, partly because of low salt content and high moisture. These compositional factors along with manufacturing procedures that are typically used for Sudanese white cheese making induce excessive growth of starter organisms (Ardo, 1993; Mistry and Kasperon, 1998).

Hydrophobic compounds produced by proteolysis are perceived with greater intensity of bitterness in Sudanese white cheese than in full-fat cheeses because these compounds are absorbed by fat (Olson and Johnson, 1990). Bitterness in low-fat cheddar cheese may be lowered by increasing the salt in moisture phase of cheese to $> 4.5\%$ to control microbial activity, but this also makes the cheese harder (Mistry and Kasperon, 1998). Milk fat contain short chain fatty acids that when released through the activity of lipase contribute to the overall cheese flavour, when fat content is lowered these fatty acids are present in lower amounts and the cheese may be perceived as lacking flavour. The greater the reduction in fat the more intense these effects will be. The simple act of washing curd during remanufacture of Sudanese white cheeses for increasing moisture content and removing lactose will also lead to bland flavour (Johnson, *et al.*, 1998). Further- more, in ripened cheeses such as low-fat cheddar cheese and imbalance in flavour during ripening is also observed along with the development of bitterness (Muir, *et al.*, 1992). Methanethiol, for example, is important flavour compound in some cheeses (Fox *et al.*, 1993). Dimos *et al.* (1996) found that in low-fat cheddar cheese of 7% fat, the concentration

of methanethiol was about half that found in full-fat cheddar during ripening. This was suggested as being responsible for the perceived flavour defects in low-fat cheddar. Milo and Reineccius (1997) attributed meaty-broth flavour defect in low-fat cheddar cheese to farandole, homofuraneol and methional. Furthermore, because of critical role of fat in the flavour, texture and appearance of food, it quickly becomes obvious that developing low-fat products with a quality matching that of their full-fat counter-parts is a fairly difficult task, when one is replacing fat with alternative ingredients (Romeh *et al.*, 2002).

In cheese the removal or reduction of fat adversely affects both flavour and texture (Metzger *et al.*, 2001; Koco and Metin, 2004; Madadlou *et al.*, 2005). Sudanese white cheese is usually identified as bland, firm, rubbery and defective in colour (Sipahioglu *et al.*, 1999). To over-come these defects, various suggestions have been made. Increasing the moisture content is most common preposition to overcome the usual textural defects of Sudanese white cheeses (Rodriguez, 1993). In this respect, different authors have concluded that, one of the key factors in achieving products with acceptable characteristics is maintaining the same moisture in non-fat substance (MNFS) ratio as found in full-fat cheese (Broadbent *et al.*, 2001).

Sudanese white cheeses contained significantly higher moisture and protein content than did the full-fat cheeses. Decreasing the fat content also led to a significant decrease in the level moisture non-fat substance and the ratio of moisture to protein (M.P) which was reported by (Rubdan *et al.*, 1998a; McMahan *et al.*, 1999; Dave *et al.*, 2003; Kahyaoglu and Kaya, 2003; Madadlou *et al.*, 2005).

Koca and Metin (2004) who also used fat replacer reported that at the gum concentration increased the percentage of protein decreased significantly; this occurred because of an increase in moisture content caused by the hydrophile properties of the gum and a decrease in syneresis.

The moisture content of cheese (full-fat and Sudanese white cheese) increased during ripening. The increased moisture content of cheese samples during ripening might show proteolysis, possibly because of adventitious microflora (Kaya, 2002).

A large protein of the rennet is lost in the whey during cheese making (Madadlou *et al.*, 2005) and in general, only about 6% of rennet added to cheese milk is retained in the curd (Fox, 1989).

The protein content of all treatments decreased during ripening (Khosrowshahi *et al.*, 2006). Also, they added that hypothesized decreased in protein content of Iranian white cheese during ripening.

The increase moisture content of Sudanese white cheeses induced a decrease in the fat content, leading to decrease fat in dry matter decreased during ripening, although the rate of this decrease was lower at the end of ripening (Kavas *et al.*, 2004). The moisture non-fat substance in full-fat cheese was higher than in control of Sudanese white cheeses. Because the moisture non-fat substance in cheese is related to milk fat, the reduced fat in milk (can thus in cheese) reduce the moisture non-fat substance supplementation of low-fat milk use in cheese making with gum increased the amount of moisture non-fat substance in Sudanese white cheese, to a point greater than that in full-fat cheese this could be due to the greater water binding capacity of gum (Ryhanen *et al.*, 2001).

The moisture: protein ratio (M:P) and moisture non-fat substance in all treatment increase during ripening because of the increased moisture content and decreased protein content, (Kavas *et al.*, 2004; Madadlou *et al.*, 2005). Fat and protein recoveries in the cheese were also significant affected by the fat content (Rudan *et al.*, 1999).

2.4.2 Factor affecting chemical and microbiological quality of Sudanese white cheese

2.4.2.1 Selection of milk

The composition of cheese is strongly influenced by the composition of the cheese milk, especially the content of the followings:

2.4.2.2 Fat

The fat content of cheese varies considerably depending on the milk composition (i.e. fat to protein ratio) and the method of cheese making used, which essentially controls the fat and protein content of the cheese. This is important because the ratio of fat to protein will affect firmness, mouth feel, texture and the flavour qualities of cheese (Quinee and McSweeney, 2006). Because of critical role of fat, the flavour, texture and appearance of food, it quickly becomes obvious that developing low-fat products with a quality matching that of their full-fat counterparts is a fairly difficult task when one is replacing fat with alternative ingredients (Romeih, 2002). In cheese the removal or reduction of fat adversely affects both its flavour and texture (Metzger *et al.*, 2001).

2.4.2.3 Protein

Protein is polymers of amino acids joined together by peptide bonds and are vital for the regulation of the body's cells, tissue and organs. The

function of protein in the body is dependent on the made up and order of individual amino acid within a protein (Nelson and Cox, 2005).

Caseins are the main proteins in milk and cheese, they are a family of phosphorylated protein (α s1, α 2, B and K-casines) that combine with colloidal calcium phosphate to form aggregates known as casein Mili cells (Farrell *et al.*, 2004).

Suliman *et al.* (2013) reported that the protein content of Sudanese white cheese were affect significantly ($P \leq 0.05$) by storage containers and storage period, while Dhuol and Hamid (2013) reported that there were significance difference ($P < 0.05$) in the crude protein contents between all the treatments.

2.4.2.4 Minerals

The specific quality of minerals found in cheese, as with other nutrient, differs according the manufacturing procedure of a cheese type, for example, the method of coagulation used, the acidity of the curd and the amount of salt and calcium chloride added will all have an effect on mineral concentration of cheese (Luccy and Fox, 1993). Dhuol and Hamid (2014) reported that, statistical analysis showed that cassava powder significantly ($P < 0.05$) affected the vitamin C, Ca and P, while there were no significance ($P < 0.05$) effect on Na and K contents of the white cheese. Moreover, they added that, there was significance effect ($P < 0.05$) by storage period in all the characteristics under the investigation (Vitamin, Ca, P, Na and K).

2.4.2.5 Vitamins

Vitamins are complex organic substance that fall into two classes, fat soluble and water soluble, both of which are essential for many vital functions carried out by the body with the exception of vitamin D, vitamins

cannot be made by the body and so have to be consumed in the diet. Generally, only a few milligrams or micrograms of vitamins are needed per day, but without them serious health complications can arise. As with all the nutrients found in cheese, the vitamins content is highly variable between types of cheese and within samples of some varieties of cheese. This is due to variation in the manufacturing process, the culture used, the condition of the maturation period and the vitamin content of the milk (Oste *et al.*, 1997). Most of the milk fat (80-85%) is retained in the cheese curd with most of the fat soluble vitamins (Parodi, 2004).

2.4.2.6 Standardization of milk

Milk per cheese is subjected to a number of pretreatment with various objectives. Different cheese varieties have a certain fat in dry-matter content, in effect, a certain fat protein ratio and this content has legal status in "standard of identity" for many cheese varieties (Mistry, 2001). While the moisture content of cheese and hence the level of fat plus protein is determined mainly by the manufacturing protocol. The fat: protein ratio is determined mainly by the fat casein ratio in the cheese mil. Depending on the ratio required, it can be modified by:

- * Removing some fat by natural creaming as in the manufacture of Parmigiano, Reggiano or Centrifugation.
- * Adding skim milk.
- * Adding cream.
- * Adding milk powder, evaporated milk or ultra-filtration edentate (such addition). Also blocks for protein or as source of energy in the body but they display biological activity too.

Karaman and Akalin (2013) reported that the total solids content, milk fat, salt and free fatty acid concentration all increased in the reduce and Sudanese white cheese made from homogenized cream relative to controls.

2.4.2.7 Acidity

Hamid and El Onwi (2008) reported that the high acidity of raw milk cheese could be due to the fact that the storage temperature activated the natural micro flora of milk to develop acidity as the result of lactose fermentation since the cheese was stored at room temperature. Nour El-Diam and El Zubeir (2010) found that the acidity of Sudanese white cheese made from different level of fat milk is 0.77% with non-significant differences ($P>0.05$). Moreover, acidity of Sudanese white cheese tasted after 15 and 30 days revealed 0.74% and 0.92% respectively and showed highly significant differences ($P<0.05$).

Madadlou *et al.* (2007) found that no significant differences in lactic acid and pH in reduced and low-fat Turkish white cheese. They also added that the reduction in fat and the increasing in gum concentration significantly decrease the pH of the product.

2.4.2.8 Milk coagulation

Milk coagulation is essential step in the manufacture of all cheese varieties involves coagulation of the casein component of the milk protein system to form a gel that entrap the fat. Also the majority of dairy protein that plays the important of emulsifiers are casein, the emulsification potential of which is improved by the use of chelating salts. This solubilized casein is able to interact with water and fat under agitation and heating and on cooling will form a gel structure (Siew and Henning, 2004).

2.4.2.9 Sodium chloride (NaCl)

In the most cheese, common salt (NaCl) is added had three major functions in cheese, it act as preservative, contributes directly to the flavour and is a source of dietary sodium (Quinee, 2004). Salt can be added directly into the curd as the cheese is being made e.g. cheddar, rubbed onto the outside of the cheese, e.g. some blue cheese, or the cheese can be immersed directly in a vat of brine e.g. Edam and Emmental, depending on the variety of cheese being made (Robinson and Wilbey, 1998).

El-Bakry (2012) reported that almost all of the dietary sodium comes from processed foods, to which various types of cheese belong, consumed in western countries. Cheese is a versatile nutrient-dense dairy food, however, it is perceived as containing high levels of fat and sodium (Ali and Abdel Razig, 2011; Salih *et al.*, 2011). Moreover, headed that the primary role of salt is to act as a preservative due to its ability to reduce the water activity that prevents the growth of most undesirable microorganism. In addition Aly and Galal (2002) reported that chloride ion also inhibits the germination of microbial spores. Salt is usually added to control the growth of lactic acid bacteria and to prevent undesirable microbial growth by killing or limiting the growth of food borne pathogens and spoilage microorganism.

2.4.2.10 Calcium and phosphorus

The equilibrium between calcium and phosphorus is important for successful coagulation of curd during cheese making (Wolfshoon-Pombo, 1997). Addition of calcium chloride is important for cheese making because it reduce the rennet coagulation time of milk, increase get, firmness reduces

the amount rennet required and increase the concentration of calcium found in the cheese (Kruif and Holt, 2006).

2.5 Fat replacer and other additives

Various additives are applied in low fat cheese making with a few to actually replacing the void left by fat in terms of its sensory and functional characteristics. These additives include various commercially available fat replacers as well as blends of stabilizers that help in moisture retention. While fat replacers are ingredient intended to be used in the place of natural fats with the objective of obtaining a reduction in caloric value (Huyghebaert *et al.*, 1996). Ingredients such as Gums, carrageenan, cellulose gels, gelatin and starch-based products such as cassava powder, Cardamom, Cinnamon and Fenugreek (Hamid and Abdelrahman, 2012; Dhoul and Hamid, 2014) have been used in other dairy products and have application in Sudanese white cheese as well.

2.6 Ripening of Sudanese white cheese

Cheese ripening is complex process involving arrange of biochemical reaction. High densities of microorganisms are present in cheese throughout ripening and they play a significant role in the maturation process (Cogan, 2000). Moreover, cheese ripening is a complex process that includes the breakdown of the curd by proteolysis, lipolysis and other enzyme catalyzed reactions which cause flavour and textural changes typical of different varieties (Ihsan *et al.*, 2011), they added that, proteolysis and lipolysis are the most significant biochemical events that occur during cheese ripening- proteolysis plays a major role in the development of texture and flavour in most rennet curd cheese varieties ripening (Fox, 1989).

Lipolysis is also an important phenomenon in cheese ripening and its low levels contribute to the ripening of some cheese varieties, but excessive levels of lipolysis are undesirable and result in rancidity (McSweeney, 2004).

Kim *et al.* (1992) reported that fat and protein tended to increase due to rapid decrease of moisture content during ripening, proteolytic and lipolytic processes are paramount to obtain characteristics properties of ripened cheese. Stadouders *et al.* (1983) showed that, proteolytic breakdown of B-casein and subsequent development of bitterness was strongly retarded by the presence of salt. Liptopoula-Tzantakis (1992) studied the ripening of the white-brine cheese and stated that, anaerobic, lactic acid, proteolytic, lipolytic and psychrophilic bacterial counts were isolated after 75 days of ripening and the low pH (4.5) and high NaCl (5.8-6.2) content of cheese inhibited microbial growth causing bacteria counts to decrease considerable after 3 months. Crude protein content of white cheese slightly decreased during ripening, because some nitrogenous compound diffuse into the brine) as reflected by the concomitant increase in the level of water-soluble protein in the brine during ripening (Karakus and Alperden, 1995).

2.7 Gum Arabic and starches

Gum Arabic refers to dried exudates obtained from the stems and branches of *Acacia Senegal* or *Acacia seyal*. The exudates is a non-viscous liquid, rich in soluble fibers and its emanation from the stems and branches usually occurs under stress conditions such as drought, poor soil fertility and injury (Willisams and Phillips, 2000). According to Elhassaneen *et al.* (2014), Gum Arabic, structurally is a neutral or slightly acidic salt of a

complex polysaccharide composed of galactose, arabinose, rhamnose, glucuronic acid, 4-O-methyl glucuronic acid, calcium, magnesium and potassium.

Gums and starches are often used as fat replacers, fiber-bearing ingredients and low carb alternatives in food products, (Drake, *et al.*, 1996). Most fat-reduced food product relies on starches and gums and their ability to regulated moisture to help simulate the bulk and mouth feel of the removed fat. Gums starches and other additives ingredient provide some of the functions of fat in feeds by binding water and providing texture and mouth-feel (Kavas, *et al.*, 2004; Koca and Metin, 2004).

2.7.1 The health benefits of use Gum Arabic as fat replacer

An excessive consumption of fat has been associated with an increased risk of health problems such as obesity, diabetes and cardiovascular diseases (Lakovchenko and Arseneva, 2016).

The use of Gum Arabic dates back to the year 2000 BC when the Egyptians used it and called “Gum Arabic” because was exported from Arabian ports (Abdul, 2002). Today, the properties and feature of Gum Arabic have been widely exported and developed and it is being used in a wide range of industrial sectors such as textiles, ceramics, lithography, cosmetics, pharmaceuticals and food, regarding food industry. Gum Arabic is approved for use as a food additive by the U.S. Food and Drug Administration and is on the list of substance “generally recognized as safe” (CFR, 1974). Gum Arabic is used as a stabilizer, flavor, fixative, a thickener, an adhesive and/or an emulsifier agent (Verbeken *et al.*, 2003).

Additionally many studies has confirmed the effective biological role of Gum Arabic including reduction in plasma cholesterol level in animals

and humans, anticarcinogenic effect (Nasir *et al.*, 2010), antioxidant effect (Al-Majed *et al.*, 2002; Ali, *et al.*, 2003; Trommer and Neubert, 2005; Ali and Almoundhri, 2006) with a protective role against hepatic and cardiac toxicities. In addition to that, it has been claimed that Gum Arabic alleviates effects of chronic renal failure in humans (Ali *et al.*, 2010).

Also Gum Arabic is indigestible to both humans and animals, not degraded in the intestine, but fermented in the colon to give short chain fatty acids, leading to a large range of possible health benefits (Phillips and Phillips, 2011); one of these benefits is its prebiotic effect (Phillips *et al.*, 2008).

Calame *et al.* (2008) reported that four week supplementation with Gum Arabic (10 g/day) led to significant increase in Bifidobacteria, Lactobacteria and Bacteriodes indicating a prebiotic effect. Several epidemiological studies suggest that a high intake of dietary fiber, including Gum Arabic (dietary fiber > 80%), is associated with beneficial effects on fat metabolism (Slavin, 2003 and Ali, *et al.*, 2009). It can serve to reduce obesity and therefore prevent associated complications in humans including coronary heart disease, stroke and diabetes (Lear *et al.*, 2003 and Hedley *et al.*, 2004). Therefore, there is substantial evidence that Gum Arabic can play a positive health-related role in addition to its well-known properties as a food additive. In an attempt to open up a new horizon for the use of Gum Arabic in an important nutritional and food technological applications.

2.8 Cheese packing

Recently, due to increase of population, the cheese industry has become a common sight without supervision or quality, Sudanese white cheese is delivered to the market immediately after processing, under

inadequate conditions, poor handling technique, inappropriate packaging materials and lack of adequate storage facilities. However, it seems that essential dairy products including cheese must be safe acceptable and meet consumer's satisfaction (Khalifa, 1989; Ibrahim, 2003; Elonni and Hamid, 2008). Different factors influence the quality of white cheese and therefore its nutritive value, these factors include: composition of food materials, the natural of the compounds the type of packaging system and the preservative added (Dueruet *et al.*, 2001).

Proper packaging method is very important for chemical, physical and microbial quality of white cheese. Microorganisms present in dairy products (fermented milk, cheese) belong to three groups; those responsible for transmission of food borne disease (pathogens); other that produce desirable flavour and physical characteristics. Dairy products are the major vehicle for transmission of human diseases such as *Brucellosis*, *Salmonellosis* and tuberculosis. Unless milk used for cheese processing is pasteurized or otherwise treated to destroy pathogens; pathogenic or toxic in producing organisms present in raw milk could be found in cheese (El Nasri *et al.*, 2012). Moreover, they added that, these organisms may find their way into cheese as result of environmental conditions during processing and packaging.

Most fresh cheese is packed in air atmosphere due to the short shelf life required. Some experiments proved that chemical composition and sensory characteristics, colour and body of white cheese made from pasteurized cow milk during the storage period (45 days) in vacuum packaging did significant change (Ahmed and Alhassan, 2010). Suliman, *et al.* (2013) reported that, total solids content of 1%, 2% and 4% fat of milk for making Sudanese white cheese were affect by the type of packaging

during the storage of period. El Onwi and Hamid (2009) reported that, increase in total bacteria count of Gibna Bayda made from pasteurized and boiled milk. Moreover, Atasever *et al.* (2003) showed significant variation in coliforms bacteria in cheese as affected by package. Also, they added that, *E. coli* in cheese packaged in two types of packages.

The increase in cheese production in Sudan witnessed a retreat times and sealed by soldering. However, soldering of cheese metal packages was prohibited and accordingly the packaging of cheese was changed to metal and plastic press lid containers (Idris and Alhassan, 2012).

Abdalla and Mohamed (2009) investigated the effect of vacuum packaging on chemical composition and sensory properties of white soft cheese and found that sensory properties are gradually improved. However, vacuum packaging is currently not feasible in rural area of Sudan where the majority of cheese is produced. In laboratory trial, Nour El Diam and El Zubeir (2007) reported that glass packaging was more acceptable compared to plastic packaging (70% and 30%, respectively).

2.9 Cheese storage and handling

Various types of cheeses have a short shelf life whereas other cheeses are adapted to extended storage. During storage cheese develops properties that are characteristics of a particularly type of cheese (Fox *et al.*, 1993).

According to Suliman *et al.* (2013) Sudanese white cheese was affected by the types of packaging materials (glass and plastic) and stores at (the room temperature) $38\pm 2^{\circ}\text{C}$ and the refrigerator $5\pm 3^{\circ}\text{C}$. During storage period duration (3 months). The results revealed that, the fat levels of Sudanese white cheese showed significant differences ($P < 0.05$) content of total solids, protein, fat, ash, acidity and total volatile fatty acids. In addition the different packaging materials (glass and plastic) and storage duration

showed significant differences ($P < 0.05$) for total solids, protein, fat and ash of the cheese. The total solids, protein, fat and ash content decreased throughout the storage period and the lowest values ($31.76 \pm 0.47\%$, $13.75 \pm 0.59\%$, $4.20 \pm 0.41\%$, and $3.15 \pm 0.40\%$, respectively) were obtained after 90 days of storage. The highest acidity occurred in full-fat cheese after 90 days in both glass and plastic containers (1.27% and 1.95% , respectively) at room temperature. It was also found that the volatile fatty acids were increase with the increase of the milk fat and higher value ($62.25 \pm 2.06/0.1N$ ml NaOH/100 gm cheese) was observed in plastic in plastic container after 90 days of storage. However, El Onwi and Hamid (2007) reported that, Gibna Badya was affected by the period of storage. But usually affected by some of microbial hazards such as *E. coli*, *Salmonella spp.*, and *Staph aureus* (Warasma *et al.*, 2006). Moreover, they added that, the weight loss, crude protein, total solids and ash increased after 120 days. The total bacterial count, coliform, *E. coli*, *Staph aureus* and *psychotrophic* bacterial count decreased during storage, while yeasts and mould increased with improvement in the texture, flavour and colour of the cheese (El Onwi and Hamid, 2008).

Nour El Diam and El Zubeir (2010) studied that, Sudanese white cheese made from milk with 4.4% fat yielded more compared that made from milk with 2.2% fat, moreover they found highly significant ($P < 0.001$) variations in the level of total solids, protein, fat and ash of the Sudanese white cheese made from different fat levels of milk, ripening time of Sudanese white cheese also the different storage period and the packaging materials. In Sudan different investigator reported variable results. Elhassen *et al.* (2014) found that the fat content of lime cheese and grapefruit cheese samples stored in refrigerator were high, while the fat contents of the same

cheese stored in whey at room temperature were low. The protein content of lime cheese stored in refrigerator ($19.45 \pm 3.06\%$) whey at room temperature ($16.28 \pm 1.29\%$) was higher than that of grapefruit cheese (17.03 ± 2.83).

Total solids content of the lime cheese stored in whey at room temperature increased significantly ($P \leq 0.001$) from $45.51 \pm 1.3\%$ at week one to $66.94 \pm 1.48\%$ at week four, ash content of lime cheese samples stored in whey at room temperature ($1.10 \pm 26\%$) was significantly ($P \leq 0.001$) higher than those of lime cheese stored in refrigerator ($0.05 \pm 0.01\%$). Acidity of lime cheese stored in whey increased significantly ($P \leq 0.001$), the acidity of lime cheese stored in refrigerator increased from $0.20 \pm 0.00\%$ at week one to $0.30 \pm 0.00\%$ at week four. They concluded that the storage period has significant effect on the chemical composition of white cheese made with lime and grapefruit extracts; also the method of preservation had clear effect on the chemical composition of the white cheese (Elhassen *et al.* (2014).

2.10 Defects in white cheese during storage

The secondary microflora might make a beneficial contribution to the development of cheese flavour; components of the same microflora can, on occasions, cause defects. The most common defect of white cheese and similar cheeses is "early blowing", a defect that is characterized by the presence of large gas holes in the cheese, which, in addition, has a spongy texture, this defect is due to coliforms and/or yeasts growing in excessive numbers (Romano *et al.*, 1989). However, the problem is rare in modern dairies, provided that efficient pasteurization and good manufacturing practices are applied. Furthermore, the activity of the starter is crucial in the control of coliforms by decreasing the pH and the amount of lactose in the curd (Roman *et al.*, 1989).

The presence of coliforms in cheese, particularly *Aerobacter aerogenes*, has been reported to be responsible for blown tins of domiati cheese (Abdel Salam, 1987), a salt content in the milk of 90 g^l-1 can prevent this defect. *Klebsiella aerogenes* was found to be responsible for early blowing and poor cheese quality in other white-brined cheese, (Abo Elnaga, 1971).

Excessive yeast growth will cause softening of cheese, a condition that is usually associated with an unpleasant yeast or ester-like odour (Seiler and Busse, 1990), or gas formation (Vivier *et al.*, 1994). In the case of white-brined cheeses, swelling of the cans be caused by yeasts that ferment lactose e.g. *Kluyveromyces spp.* Discolouration of the surface of a "Portugues ewes" milk cheese has been attributed to pigment-producing yeasts (Carreira *et al.*, 1998). In addition, yeasts can increase the pH of the cheese surface, thus spurring the growth of *Staphylococcus aureus* (Nussinovitch *et al.*, 1987), and possibly other pathogenic and/or spoilage bacteria. For feta stored over a year, a definite deterioration of quality was noticed when the pH of the cheese increased to more than 5.0 (Veinoglou *et al.*, 1979).

Late blowing is another defect in cheeses, and this problem is usually attributed to hetero-fermentative lactic acid bacteria or species of clostridia (e.g. *Clostridium butyricum* and *Clostridium tyrobutyricum*). Although the latter group are sensitive to acid and salt and are more usually associated with problems in Swiss-type and Dutch-type cheeses (Chapman and Sharpe 1990; Walstra *et al.*, 1993). Some strains of *Clostridium tyrobutyricum* are acid-resistant (growing well in 2.5-7.5 pH zone) and relatively that the leuconostocks were frequently found at the beginning of the ripening of

white-brined cheese (Brinza-type), while the pediococci were more numerous in late phase of the maturation.

Yanai *et al.* (1977) reported that, coliforms were found in white brined cheese, even though they were absent from the pasteurized milk and the starter culture, but their number declined in parallel with the reduction in pH. In batzos cheese a raw ovine milk cheese manufactured in North Greece, Enterobacteriaceae and coliforms decreased in number gradually and, by the end of storage, the count were lower by 2-3 log units over the initial ones (Nikolaou *et al.* 2002), the lower pH of the cheese manufactured during the summer resulted in lower numbers of coliforms in cheese.

It has been recognized that micrococci produce proteolytic, esterolytic and lipolytic enzymes that can have a beneficial role in the development of the flavour and aroma of the cheeses, only low numbers of micrococci have been detected because the low pH of the cheese and the brine inhibit their growth (Yanai *et al.*, 1977).

2.11 Microorganisms in cheese

The use of milk product as human food got a very long history (Teuvo, 2000). Milk in addition to be nutritious media presents a favourable physical environment for multiplication of microorganisms (Mohamed and El Zubeir, 2007). Yagoub *et al.* (2005) stated that milk is good medium for bacteria including pathogenic organisms and if it is produced and processed under unhygienic conditions, frequently outbreaks of disease result.

Warsama *et al.* (2006) cited that the spread of some disease by cheese have been demonstrated and as result, most cheese is now produced from milk that has been pasteurized and it is indisputable that some outbreaks of

food-borne illness have been clearly linked with the consumption of cheese, the majority of those reported being associated with cheese made from unpasteurized milk, Whilst pathogens can gain access to cheese after curd formation, moreover, they showed different types of the potentially food-borne disease (*E. coli*, *Salmonella spp.* and *S. aureus*) which were found in Sudanese white cheese, unless milk used for cheese processing is pasteurized or otherwise treated to destroy pathogens, pathogenic or toxin producing organisms present in raw milk could be found in cheese (Jay, 2000).

Melilli *et al.* (2004) reported that low initial salt and higher bringing temperature (18°C) allowed for greater growth of coliforms, which cause gas formation in the cheese. Moreover, if extensive proteolysis occurs during aging of ripened cheeses, the release of amino acids and concomitant increase in pH favours the growth of clostridia, specially *Clostridium tyrobutyricum*, and the production of gas and butyric acid (Klijn *et al.* (1995). Spores are concentrated in cheese curd, so as few as one spore per milliliter of milk can cause gassiness in some cheeses (Myhara and Skurgz, 1990) Coliforms, like psychotrophs can also reduce the diacetyl content of butter milk and sour cream (Wang and Frank, 1981), subsequently producing a yoghurt-like flavour. In cheese production by starter cultures, favours the growth and production of gas by coliform bacteria, with coliforms having short generation times under such conditions. In soft, mold-ripened cheeses, the pH increase during ripening, with increase the growth potential of coliform bacteria (Frank, 2001).

Lactic acid bacteria excessive viscosity can occur in butter milk and sour cream from growth of encapsulated, slime-producing lactococci. In

addition, diacetyl can be reduced by diacetyl reductase produced in these products by lactococci growing at 7°C (Hogarty and Frank, 1982). Moreover, heterofermentative lactic acid bacteria such as lactobacilli and leuconostoc can develop off-flavours and gas in ripened cheese. These microbes metabolized lactose, subsequently producing lactose, acetate, ethanol and CO₂ in approximately equimolar concentration (Hutkins, 2001). When the homo-fermentative lactic acid bacteria fail to metabolize all the fermentable sugar in cheese, the hetero-fermentative bacteria that are often present complete the fermentation, producing gas and off-flavour, provided their population are to 10⁶ cfu/g (Johnson, 2001).

The low pH and the nutritional profile of most cheese are a favourable for the growth of spoilage yeasts. Surface moisture, often containing lactic acid, peptides and amino acids favours rapid growth. Many yeasts produce alcohol and CO₂, resulting in cheese that tastes yeast (Carreira et al 1998; Roostita and Fleet 1996)

2.11.1 Spoilage microorganisms in cheese

Food spoilage is metabolic process that causes foods to be undesirable or unacceptable for human consumption due to changes in sensory characteristics. However, spoiled foods may be safe to eat, i.e. they may not cause illness because there are no pathogens or toxin present, but changes in texture, smell, taste or appearance cause them to be rejected. Some ecologists have suggested these noxious smells are produce by microbes to repulse large animals, thereby keeping the food resource for themselves (Burkepile De *et al.*, 2006).

Trouble some spoilage organisms include aerobic psychrotrophic Gram-negative bacteria, yeasts, mould, heterofermentative lactobacilli and

spore-forming bacteria. Psychrotrophic bacteria can produce large amount of extracellular hydrolytic enzymes and the extend of recontamination of pasteurized fluid milk products with these bacteria is the major determinant of their shelf life (Jay, 2000). Fungal spoilage of dairy foods is manifested by the presence of a wide variety of metabolic by products, causing off odours and flavours, in addition to visible changes in colour or texture (Ceylan *et al.*, 2003). Coliforms, yeasts, hetero-fermentative lactic acid bacteria can all cause gassing defects in cheese (Walstra *et al.*, 1999).

Several microorganisms grow in cheese and on cheese surface made from raw milk, which cause texture and flavour defects such as gas production, souring and yeasty, putrid, fruity and hydrogen sulfide flavour (Walstra *et al.*, 1999; Jay, 2000).

The spoilage organisms in cheese and dairy products are coliforms, yeast and moulds, propionic acid bacteria, faecal *Streptococci*, *Lactococcus lactis* and psychrotrophic bacteria (Ceylan *et al.*, 2003). Dairy product such as milk, butter, cream and cheese are all susceptible to microbial spoilage because of their chemical composition (Jay, 2000). Moreover, products range from those that are readily spoiled by microorganisms to those that are shelf stable for many months and the spoilage rate influenced by factors such as moisture content, pH, processing parameters and temperature of storage (Lempert, 2004).

Factors that determine the rates of spoilage of cheese are water activity, pH, salt to moisture ratio, temperature, characteristics of the lactic starter culture, and types of viability of contamination by microorganisms and characteristics and quantities of residual enzymes. With some any variable to affect determinative reactions, it is no surprise that cheeses vary widely in spoilage characteristics. Soft or unripened cheeses, which

generally have the highest pH values, along with lowest salt to moisture ratio, spoil must quickly. In contrast, aged, ripened cheeses retain their comparatively low pH, low water activity and low redox potential. For fresh raw milk past Filata cheeses (Melilli *et al.*, 2004) found that low initial salt and higher bringing temperature (18°C) allowed for greater growth of coliforms, which caused gas formation in cheese.

Brocklehurst and Lund (1988) reported that once factors affecting the growth of the spoilage microorganisms, *Enterobacter agglomerans* and *Pseudomonas spp.* in cottage cheese. While Standhaders (1990) mentioned that some of the spoilage microorganisms were able to grow at relatively low pH values (4.6-4.7) when incubated at 7°C and were able to grow at pH 3.6 when grow in media at 20°C. Moreover, he added that, rate of salt penetration into brine cheeses, types of starter cultures used, initial load of spores in the milk use for production, pH of the cheese and ripening temperature affect the rate of butyric acid fermentation and gas production by *Ctyrobutyricum*.

Fungal growth in package cheeses was found to be most significantly affected by the concentration of CO₂ in the package and the water activity of the cheese (Nielsen and Haasum, 1997).

Cheddar cheese exhibiting yeast spoilage had a high moisture level (39.1%) and a low salt in the moisture-phase value (3.95%) (Horwood *et al.*, 1987). While Roostita and Fleet (1996) reported that the properties of yeast that affected the spoilage rate of Camebert and blue veined cheeses were the abilities to ferment/assimilate lactose, produce extracellular lipolytic and proteolytic enzymes, utilize lactic and citric acid and grow at 10°C.

2.11.2 Spore forming bacteria

Spore-forming bacteria are usually associated with spoilage of heat-treatment foods because their spore can survive high processing temperature. These Gram-positive bacteria may be strict anaerobes or facultative (capable of growth with or without oxygen). Some spore-formers are thermophilic, preferring growth at a high temperature (as high as 55°C). Also some anaerobic thermophiles produce hydrogen sulfide (*Desulfotomaculum*) and others produce hydrogen and carbon dioxide (*Thermonan aerobacterium*) during growth on canned/hermetically sealed foods kept at high temperature, others thermophiles (*Bacillus* and *Geobacillus spp.*) cause a flat sour spoilage of high or low pH canned food with little or no gas production and one species causes ropiness in bread held at high ambient temperature (Pepe *et al.*, 2003).

Mesophilic anaerobes, growing at ambient temperature, causes several types of spoilage vegetables (*Bacillus spp.*); putrefaction of canned products, early blowing of cheeses, and butyric acid production in canned vegetable and fruits (*Clostridium spp.*) and medicinal flavour in canned low acid foods by *Alicyclo bacillus* (Changss and Kang, 2004).

2.11.3 Lactic acid bacteria (LAB)

LAB are a group of Gram-positive bacteria including species of *Lactobacillus*, *Pediococcus*, *Leuconostoc* and *Gonococcus*, some of which are useful in producing fermented foods such as yoghurt and pickles. However, under low oxygen, low temperature and acidic conditions, these bacteria become the predominant spoilage organisms on a variety of foods (Abassi, 1992). Undesirable changes caused by lactic acid bacteria include greening of meat and gas formation in cheese (blowing), pickle (bloater

damage) and canned or packaged meat and vegetables. Off-flavour described as mousy, cheesy, malty, acidic, buttery or liver-like may be detected in meat, milk or juices spoiled by these bacteria (Abdalla *et al*, 2005). LAB may also produce large amount of an exopolysaccharide that cause slime on meats and ropy spoilage in some beverages (Abassi, 1992).

2.11.4 *Staphylococcus aureus*

The genus *Staphylococcus* is composed of species that are gram-positive cocci, non-motile, catalase-positive and facultative anaerobic. Natural populations are associated mainly with skin, skin glands, mucous membrane of warm blooded animals (Walstra et al 1999). *S. aureus* produces acid from mannitol, glucose, lactose and maltose in aerobic and anaerobic conditions (Banwart, 1981). *S. aureus* is widespread in nature; however, the main reservoirs are the nasal cavities from where it finds its way to the skin. The most common skin sources are the arms, hands and face. It is also found in the eyes, throat and the intestinal tract (Jay, 1986; Benwart, 1989).

It is believed that 10^5 to 10^6 cells of *S. aureus* per gram must be present before enterotoxin is produced to a level that causes intoxication (Benwart, 1989). Various foods have been involved in Staphylococcal outbreaks including meat products, poultry products, bakery products and dairy products (Benwart, 1989; Bergdoll, 1989).

2.11.5 *Pseudomonas*

Pseudomonas and related genera are aerobic, Gram-negative soil bacteria, some of which can degrade a wide variety of unusual compounds. They generally required a high water activity for growth (0.95 or higher)

and are inhibited by pH values less than 5.4. Some species grow at refrigeration temperatures (psychrophilic) while other are adapted for growth at warmer, ambient temperatures (Marshall, 1992). Four species of *Pseudomonas* (*P. fluorescens*, *P. fragi*, *P. lundensis* and *P. viridiflava*). *Shewanella putrefaciens* and *Xanthomonas compestris* are the main food spoilage organisms in this group. In animal derived foods (meat, milk) causes spoilage by secreting lipases and proteases that cause formation of sulfide and trimethylamine (off-odour) and by forming biofilms (slime) on surfaces (Fonnesbechvogel *et al.*, 2005; Hozbor *et al.*, 2006).

2.11.6 Enterobacteriaceae

Enterobacteriaceae are Gram-negative, facultatively anaerobic bacteria that include a number of human pathogens *Salmonella*: *E. coli*, *Shigella*, *Yersinia* and also a number of spoilage organisms. These bacteria are widespread in nature in soil, on plant surfaces and in the digestive tracts of animals and are therefore present in many foods (Foley *et al.*, 1974). *Erwini carotovora* is one of the most important bacteria causing soft rot of vegetables in the field or stored at ambient temperature. Biogenic amines are produced in meat and fish by several members of this group, while others produce off-odours or colours in beer (*Obesumbacterium*, cheeses (several genera), Cole slaw (*Klebsiella* and shell eggs (*Proteus*, *Enterobacter*, *Serratia*) (Bryan, 1993). Temperature, salt concentration and pH are the most important factors determining which if any, of these microbes spoil foods (Foley *et al.*, 1974). Many gram-negative bacteria, including Pseudomonads and Enterobacteriaceae secrete acylhomoserine lactones (AHLs) to regulate the expression of certain genes, such as virulence factors as a function of cell density.

These ALHs quorum-sensing signals may regulate proteolytic enzyme production and iron chelation during spoilage of some foods (Rash *et al.*, 2005). Although the role of these signals in other spoilage systems is not clear (Bruhn *et al.*, 2004; Liu, *et al.*, 2006).

2.11.7 Propionic acid bacteria (PAB)

PAB are Gram-positive short, rod-shaped bacteria which metabolize lactate by the following pathway



(May *et al.*, 2004. they grow in many cheese varieties during ripening and are the characteristic microflora associated with Swiss-type cheeses such as Emmental, Gruyere, Appenzell and Comte (Steffen, 1973). Two major groups within the genus are recognized, the "cutaneous" and the "classical or dairy".

PAB are the most important with respect to cheese microbiology and five species are currently recognized: *P. freudenreichii*, *P. jensenii*, *P. thoenii*, *P. acidipropionic* and one *P. coccoides* proposed (Vorobjeva, 1999).

In cheese manufactured from raw milk, sufficient wild PAB were present, however, with the advent of pasteurization, PAB are now added to the cheese milk at the beginning of manufacture to ensure that they are present at approximately 10^7 cfu/g of cheese post manufacture (Vorobjeva, 1999). During cheese ripening, the temperature is increased from 18°C to 22°C for a short time to initiate propionic acid fermentation, with a resultant increase in level of PAB from 10^8 to 10^9 cfu/g cheeses (Steffen *et al.*, 1993). Moreover, in Swiss-type cheese undergo propionic acid fermentation in 20-30 days post-manufacture and the propionic and acetic acids produced

contribute to the development of characteristics flavour of the cheese while the CO₂ evolved is responsible for the large eyes produced (Baer, 1995).

Subsequent to the development of sufficient eyes, the cheese is stored at a lower temperature to retard further growth and metabolism of PAB. Baer (1995) demonstrated that, growth of PAB in milk-based medium was poor, however, growth could be stimulated following proteolysis by rennet and starter bacteria. Moreover, recently it was reported that growth of PAB in milk or in whey did not occur unless the initial cell density more than 10⁶ cfu/ml. The growth inhibition to be due to a heat stable inhibitors present in whey. Pre-growth of some lactic acid bacteria, used as starter culture in Swiss-type manufacture, in the milk medium removed the inhibition, the develop of PAB in Swiss type cheese from low densities even though they are inhibited in milk (Piveteau *et al.*, 2000).

Spontaneous autolysis of *P. freudenreichii* in synthetic media was demonstrated by Lemee *et al.* (1995). However, in Swiss cheese no evidence of autolysis of *P. freudenreichii* during ripening as measured by release of intracellular enzymes was detected by Valence *et al.* (1998). In gram cheese, where PAB can result in late blowing, damaged cell of *P. freudenreichii* were detected by scanning electron microscopy, suggesting that particular cheese environment autolysis did occur (Capp *et al.*, 1997).

Bacteriophage infection of *P. freudenreichii* during growth in Swiss-type cheese was recently demonstrated (Gautier *et al.*, 1995). Such infection may contribute to PAB lyses during cheese ripening. Interactions between PAB and other bacteria play a significant role during cheese ripening. Alekseeva *et al.* (1993) reported that nine out of twenty two strain of lactic acid bacteria (LAB) tested were antagonistic for PAB. *L. lactis spp. cremoris*, *S. thermophilus* and *L. helveticus* were compatible with *P.*

freudenreichii and *P. shermanii*. Jimeno *et al.* (1995a) reported that, *Lb. rhammosus* and *Lb. casei* inhibited the growth of *P. freudenerichii* in hard Swiss-type cheese.

Piveteau *et al.* (2000) studied the interaction between 14 latic acid bacteria, including strains of *Lb. helveticus*, *Lb. acidophilus*, *Lb. lactis*, *S. thermophilus* and *Lc. lact is* and four strains of PAB , either *P. freudenreichii* or *P. acidipropionic*, in whey, stimulation or inhibition was judged by the effect on growth rate and final cell biomass. No inhibition was observed by *Lb. heveticus* and *S. thermophilus*. The consequences of such stimulatory and inhibitory interaction between PAB and other cheese microorganisms needs to be considered in more detail due to the impact of such interactions on cheese quality.

2.12 Yeast and moulds

Yeast are single-celled microorganism that are classified, along with molds and mushroom, as members of the Kingdom fungi, yeasts are evolutionally diverse and therefore classified into two separate phyla, Ascomycota or sac fungi and Basidiomycota or higher fungi, that together form the subkingdom Dikarya (Herschedoerfer, (1968). Budding yeast, also referred to as "true yeasts" are members of the phylum Ascomyota and the order saccharomycetales. Such classifications are based on characteristics of the cell, ascospore and colony as well as cellular physiology (Botstein and Fink, 2011). Moreover, yeasts are a subset of a large group of organisms called fungi that also includes moulds and mushroom. They are generally single-celled organisms that are adapted for life in specialized usually liquid, environment and unlike some moulds and mushrooms do not produce toxic secondary metabolites (Nielson and Hassura, 1997). Yeast

can grow with or without oxygen (facultative) and are well known for their beneficial fermentation that produces bread and alcoholic drinks (Kurtzman, 2006; Smits and Brul, 2005).

Elnasri *et al.* (2012) found that the differences between maximum values of yeast and mould counts for cheese packaged plastic containers and minimum values were 0.00 and 0.16 respectively, indicating significant differences between the two packaging materials ($P \leq 0.05$) However, Ibrahim (2003) found that yeasts constituted the primary microbial group of white cheese collected from Khartoum market, with counts ranging from 10 to 20 colonies per gram of cheese.

Hamid and El Onwi (2008) reported that yeast and moulds were significantly ($P < 0.05$) increased with progress in storage time from $\log 2.66 \pm 0.47$ at day zero to 3.13 ± 2.15 , 4.79 ± 2.20 , 4.23 ± 1.54 and 6.95 ± 2.35 cfu/ml at day 60, 120, 180 and 240 respectively. Also they found that mould counts in the cheese with 4% salt were significantly ($P < 0.05$) higher than those of cheese with 6% salt. While Nour El Daim and El Zubeir (2007) studied manufacture and evaluation of processed cheese made from Sudanese white cheese, they found that total mould and yeast counts were 4.1×10^5 , 3.8×10^5 for the cheese made from different ripening time of Sudanese white cheese, there was highly significant differences ($P < 0.001$) with yeast and mould counts.

Moulds are considered to be microbes and do not form a specific taxonomic or phylogenetic grouping, but can be found in the divisions, Zygomycota and Ascomycota. In the past most moulds were classified within the Deuteromycota (Nielsen and Haasum 1997). Moreover, certain moulds species are essential for ripening of some varieties of cheese. Mould growth on most cheeses is undesirable. The most common ones found in

cheese are *Pencillium spp.*, *Cladosporium*, *Murcor* and *Geotricum* species (Nielson and Hassuri, 1997). Also moulds are filamentous fungi that do not produce large fruiting bodies like mushrooms. Moulds are very important for recycling dead plant and animals remains in nature but also attack a wide variety of foods and other materials useful to humans (Marins *et al.*, 2005). They are well adapted from growth on and through solid substrates, generally produce air-borne spores, and required oxygen for their metabolic processes. Most moulds grow at very low water activity level (0.7-0.8) on dried foods. Spores can tolerated harsh environmental conditions but most are sensitive to heat treatment (Marins *et al.*, 2005).

2.15 Sensory quality of white cheese during storage

The quality of cheese depends on a variety of factors among which raw milk composition, technological process parameters, bacteria species, storage, transportation and delivery conditions (Rotaru *et al.*, 2008). Hamid (1998) added that storage of cheeses at room temperature for 4 months had a slight effect on its chemical composition. However, the storage has a more pronounced effect on the quality and reological properties of cheese.

El Onwi and Hamid (2008) reported that, the results of sensory characteristics were consistent with those reported by Abdel Razig (1996) and Tarakci and Kucukoner (2006). The improvement in texture from day zero to day 120 indicate clearly the effect of storage time. Also Aly and Galal (2002) and Topcu and Saldamli (2006) reported that the textural attributes of Turkish white cheese were significantly ($P < 0.05$) affected by the ripening period. However, the deterioration in the texture thereafter might be due to further hydrolysis of proteins at later stages of ripening. It was likely due to the effect of proteolytic agents on the protein. It

contributes to cheese off-flavour and abnormal texture through the breakdown of the released proteolytic products as amino acids, peptides into amines and acids. Advancing the ripening time leads to an increase in protein degradation of the released proteolytic products as amino acids (Hayaloglou *et al.*, 2005).

The improvement in flavour was probably attributed to the effect of lactic acid development which controls the growth of undesirable organisms (Kosikowski, 1982). The improvement in flavour might be due to the natural flora initially present in raw milk which participates in flavour production as reported by Law (1999). Chemical qualities of the cheeses including titratable acidity, pH, water-soluble-nitrogen ripening and tyrosine value had significant ($P < 0.05$) effect on flavour (Guler and Uraz, 2004; Aly and Galal, 2002).

The improvement in colour from day zero to day 120 agreed with the findings of Tarakci and Kucukoner (2006) who reported that appearance and colour scores increased generally during ripening. El Onwi and Hamid (2008) mentioned that the study disagreed with Nuser (2001) who reported that storage period did not affect the colour of Sudanese white cheese during storage for 45 days. Moreover, they added that, storage period significantly affected the weight loss, chemical composition, microbiological and sensory characteristics of Sudanese white cheese.

Suliman *et al.* (2013) reported that the level of acidity was significantly ($P \leq 0.05$) affected by fat content. However, Nour El Daim and El Zubeir (2010) found non-significant ($P > 0.05$) differences for the acidity of the processed cheese made from different fat level of the milk. Nour El Daim and El Zubeir (2010) and El Onwi and Hamid (2008) attributed the low acidity of the cheese samples stored in plastic containers

to the growth of yeast, which utilized lactic acid. The increase in acidity towards the end of storage period was mainly due to increase in lactic acid by the action of lactic acid bacteria (Hayalogu *et al.*, 2005; Tarakci and Kucukoner, 2006; El Onwi and Hamid, 2008). The cheese samples kept at the refrigerator temperature revealed lower values than those kept at room temperature. This supported by Abdalla and Hamid (2010) who reported that the high acidity of raw milk cheese could be due to the fact that storage temperature activated the natural microflora of raw milk and resulted in the development of acidity as the result of lactose fermentation.

2.14 Quality of Sudanese white cheese

The term Sudanese white cheese generally refers to cheeses whose fat content is lower than its corresponding full-fat variety. As a result, there is major shift in compositional balance of various components of cheese compared with its full-fat counterpart (Wilkinson *et al.*, 2001). Especially, as the fat content of cheese is lowered, moisture content increase and protein plays a greater role in texture development, in cheese the removal or reduction of fat adversely affect both its flavour and texture (Metzger *et al.*, 2001; Koca and Metin, 2004; Madadlou *et al.*, 2005).

The fat content of cheese varies considerably depending on the milk composition (i.e. fat to protein ratio) and the method of cheese making used, which essentially controls the fat and protein content of the cheese. This is important because the ratio of fat to protein will affect firmness, mouth feel, texture and the flavour qualities of cheese (Guinee and McSweeney, 2006).

Katsiari *et al.* (2002) concluded that the composition of various cheeses (Full or low-fat Feta-type cheese) between treatments concerning

the content of moisture in non-fat substance, the concentration of salt in moisture and the pH value. Decreasing the concentration of milk fat resulted in significant ($P<0.05$) increase in the levels of cheese moisture and protein and a significant decrease ($P<0.05$) in the content of fat in dry-matter.

Akalin *et al.* (2010) studied the improve quality characteristics of reduced and Sudanese white cheese in Turkey using homogenized cream, they found that there no significant differences between control and treatment milks for lactic acid, pH or protein content. Similar results were also reported for other cheeses (Madadlou *et al.*, 2007; Nair *et al.*, 2000) regarding the effect of cream homogization on the composition of cheese milk. However, as expected the fat and dry matter contents in reduced fat cheese milks were significantly higher than the Sudanese white cheese milk ($P<0.05$) due to the removal fat. Moreover, they mentioned that, the effect of cream homogenization on the chemical properties of reduced-fat and low-fat white cheese during ripening. They also reported that homogenized cream used in a small increase in total fat and fat in dry matter (FDM) ($P<0.05$). This is most likely, due to less fat being lost to the whey. While increase fat dry matter in homogenized reduced fat and homogenized low-fat it decrease in control cheeses from the first day of ripening until the end of ripening ($P<0.05$) period. Whilst using homogenized cream in cheese making increased the dry matter and decreased moisture in cheese during ripening, this increase in dry matter was probably caused by the significant increase in fat content (Madadlou *et al.*, 2007).

Salt concentrations increase in both group, as well as the salt in the dry matter (SDM) in homogenized low-fat (Nair *et al.*, 2000; Rowney *et al.*, 2003). However, salt and salt in the dry matter concentra-tions increased in

all the cheeses between the first and ninetieth days ($P < 0.05$) possible secondary to salt and moisture equilibration during storage. When cheese is in brine, salt moves osmotically into the cheese while water does reverse. Even after the cheese blocks are out of the brine and are ripening, this equilibration continues and salt content continues to increase (Akalin and Karaman, 2011; Goncu and AlpKent, 2005; Hayalogu *et al.*, 2002; Madadlou *et al.*, 2007).

As ripening processed, total ash content in all the cheese increased, possibly due in part to syneresis, the data demonstrated highest salt level was among the treatment cheese. This upward ($P < 0.05$) trend in ash content may be due to greater salt retention in these cheeses (Hamid and El Owni, 2008). Similar result was obtained in cheddar cheese produced from homogenized cream (Nair *et al.*, 2000).

Wendorff (2005) reported that, protein content was lower ($P < 0.05$) in the treatments groups compared to the control. Reduce protein in the treatment cheese could be a result of the higher salt content in these treatments, which enhances whey drainage.

Akalin and Karaman (2011) reported that, water-soluble nitrogen was significantly higher in controls than the treatment samples ($P < 0.05$) which could also be due to the higher salt content found in various cheeses. Not only because of increased whey loss but high NaCl concentration inhibit proteolysis resulting in higher water-soluble nitrogen concentration. Madadlou *et al.* (2007) stated that treated cheeses had similar lactic acid and pH values as cheese control cheeses. Similar results were reported for other cheeses manufactured from homogenized products (Metzger and Mistry, 1994; Nair *et al.*, 2000; Rudan *et al.*, 1998).

Moreover, Nair *et al.* (2000) reported that extent of lipolysis in cheese, stated as free fatty acids content, was higher in homogenized reduced fat (HRF) and homogenized low-fat (HLF) than control groups ($P < 0.05$). Because of free fatty acids (FFA) clumps transferred from the cheese milk to the cheese, also FFA content was increased at day one in the treatment groups.

CHAPTER THREE

MATERIALS AND METHODS

This study was carried out at the Laboratory of Dairy Science and Technology Department, College of Animal Production Science and Technology at Sudan University of Science and Technology during the period from September 2014 to January 2015.

In this study, seven treatments were carried out as follows: First treatment is a control in which fresh cow's milk with 3% fat had no additive. In the second treatment 3% fat milk cheese and 0.50 Gum Arabic was added, in the third treatment, 3% fat milk cheese and 0.75% Gum Arabic were added, in the fourth and fifth treatments, 2.5% fat milk cheese and 0.50 and 0.75 % Gum Arabic were added respectively, in the sixth and seventh treatments with 2% fat milk cheese and 0.50 and 0.75% Gum Arabic were added, respectively. In all treatments, Gum Arabic powder was added to the fresh cow's milk cheese before pasteurization.

3.1 Materials

Three hundred and fifty liters (350) of fresh cow's full cream milk were purchase from a private farm at Khartoum North and then fat percentage was determined using Gerber methods according to AOAC (2009). After that the whole quantity was divided into seven equal groups (50 liters each). Gum Arabic powder, a fine commercial salt (sodium chloride NaCl), skimmed milk powder were purchased from the local market at Bahary (Khartoum North). Rennet powder (Hansen, Denmark) of one gram per 50 liters of milk was obtained from the local market at New Halfa (eastern Sudan). Plate count agar (Mereck, 74065), Sabouraud

dextrose agar (Oxoid (M41), malt extract agar, violet red bile lactose agar and polythelene bags were purchased from El Rowbi Company of Khartoum.

3.2 Preparation of milk cheese

Fresh raw cow's milk was analyzed using Gerber's method according to AOAC (2009). The milk was then standardized by skimmed milk powder (0.5% of fat) using person's squire for percentage of fat 3%, 2.5% and 2% fat were use for preparation of cheese samples.

3.3 Cheese manufacture

Cheese was manufacture according to the method described by Ibrahim (2003) with some modification. The milk samples with 3 levels of fat (3%, 2.5% and 2%) and two level of Gum Arabic (0.50% and 0.75%) three hundred and fifty liters (350) of fresh cow's milk full-cream was divided into seven equal parts (50 liters each) and standardized by skimmeds powder milk with 0.5% of fat (using person's squire) and kept into seven separate tanks. The first part was left free without any additive of Gum Arabic powder, while in the other six groups, Gum Arabic powder was added at the levels of 0.50% and 0.75% to the milk cheese respectively. The different milk samples were pasteurized at 72°C for one minute. The milk samples were then transferred into stainless steel containers for cheese manufacture and then cool to 42°C. The milk was stirred gently for 5 minutes to avoid creaming before renneting. Rennet powder (1 gram/50 liters) was dissolved into 50ml of distilled water and added to the milk at 40°C, fine commercial salt (NaCl) was added at the level of 7% immediatly. Milk was then stirred for 10 minutes and left until coagulation

occurred. The curd was then cut into small cubes ($5 \times 5 \times 5$ cm). The curd was poured into small clean wooden molds lined with cheese cloth and pressed overnight. The manufactured cheese samples were stored in polyethylene bags (capacity 300 gram) and stored at refrigerated temperature (4°C) for 120 days. Physicochemical, microbiological and sensory evaluations of cheese samples were carried out at 0.30, 60, 90 and 120 days intervals.

3.4 Analysis of cheeses

3.4.1 Chemical analysis

3.4.1.1 Fat content

The fat was determined by Gerber's method according to AOAC (2009). In a clean dry cheese Gerber tube, 10 ml of sulphuric acid (density 1.815 gram/ml at 20°C) were poured, then 3 grams of minced cheese samples were added. Amyl alcohol (1 ml) was added to the mixture followed by the addition of distilled water. The contents were thoroughly mixed till no white particles could be seen. The Gerber tubes were centrifuged at 110 revolutions per minutes for five minutes and the tubes were then transferred to water bath adjusted at 65°C for three minutes. The fat percent was then read out directly from the fat column.

3.4.1.2 Protein content

The protein content was determined by Kjeldhal method; according to AOAC (2009) three grams of the cheese and two Kjeldhal tablets (1 gram Na_2SO_4 and equivalent of 0.1 gram Hg) were put into Kjeldhal flask. Twenty-five ml of concentrated sulphuric acid (density of 1.86 mg/ml at 20°C) were added to the flask. The mixture was then digested on a heater

until a clean solution was obtained (3 hours) and the flask were removed and left to cool. The digested sample was poured into a volumetric flask (100 ml) and diluted to 100 ml with distilled water. The distillate was received in a conical flask containing 25 ml of 4% boric acid plus three drops of indicator (bromerol green plus methyl red). The distillation was continued until the volume in the flask was 75 ml. The flask was then removed from the distillatory, the distillate was then titrated against 0.1N HCl until the end point was obtained (red colour).

Protein content was calculated as follows:

$$\text{Nitrogen (\%)} = \frac{T \times 0.1 \times 0.014 \times 20}{\text{Weight of samples}} \times 100$$

$$\text{Protein \%} = \text{Nitrogen (\%)} \times 6.38$$

Where:

- T = Titration figure
- 0.1 = Normality of HCl
- 0.014= Atomic weight
- 20 = Dilution factor
- 6.38 = Conversion factor of milk nitrogen into protein.

3.4.1.3 Total solids content

The total solids were determined according to the modified methods of AOAC (2009). Two grams of cheese sample were weighted and placed a clean dried porcelain dish. The weight of sample and dish were recorded and the dishes were heated on a steam bath for 10-15 minutes. The dishes were then placed in an oven at 100°C for three hours, after which they were transferred to dessicator to cool and then weighted. Heating, cooling and weighting were repeated several times until the difference between successive weighing was less than 0.1 gram.

The total solids content were calculated from the following equation:

$$\text{Total solids (\%)} = \frac{W_1}{W_0} \times 100$$

Where:

W_1 = weight of sample after drying.

W_0 = weight of sample before drying.

3.4.1.4 Ash content

The ash content was determined according to the method of AOAC (2009). Two grams of cheese sample were weighed in a suitable clean and dry crucible and evaporated to dryness on a steam bath. Then the sample was placed in a muffle furnace at 550°C for 2 hours, and then cooled in a desiccator and weight.

The ash content was calculated using the following equation:

$$\text{Ash (\%)} = \frac{W_1}{W_0} \times 100$$

Where:

W_1 = weight of ash.

W_0 = weight of sample.

3.4.1.5 pH measurement

The pH was determined according to Newland *et al.* (1974). The pH meter (HACCH, 1011) was used to measure the pH of cheese samples, where pH-meter was calibrated with 4.00, 7.00 and 10.01 buffer solutions. Approximately 20 ml of the suspension was poured into a small glass beaker. The pH and temperature probes were suspended in the liquid until the pH-meter indicated a stable reading.

3.4.1.6 Volatile fatty acid contents (VFA)

Total volatile fatty acids contents of cheese samples were determined by the direct distillation method of Kosikowski (1982). Ten grams of cheese were placed in a mortar and grounded with successive portions of 10% sulfuric acid until the cheese was completely emulsified then transferred to

500 ml Kjeldahl flask. The addition continued until the volume of the acid added to the sample reached 25 ml. About 17.5 grams of magnesium sulphate were added to the contents in the flask, followed by few glass bead, 250 ml of distilled water and the contents distilled. Distillation was terminated when 280 ml of the distillate were collected. The inside tube of the condenser was rinsed with 12.5 ml of neutral alcohol to remove the insoluble volatile acids combined with distillate and titrated with 0.1N NaOH. The total volatile fatty acids contents were expressed as ml of 0.1N NaOH that neutralized the distillate from 100 grams of cheese.

3.5 Microbiological analysis

The sample were examined for total bacteria count (TBC), lactic acid bacteria (*Lactobacilli*, *Streptococci*), coliform, yeast and moulds counts.

3.5.1 Sterilization of equipment

Glassware such as flask, test tubes, Petri dishes, pipettes and bottles were sterilized in hot oven at 170°C for two hours, whereas distilled water was sterilized by autoclaving at 121°C for 15 minutes (Marshall, 1992).

3.5.2 Preparation of sample dilution

Eleven grams from a homogenous cheese sample were added to 99 ml of sterile distilled water in a clean sterile flask then shaken to make 10^{-1} dilution. One ml from the dilution (10^{-1}) was aseptically transferred to 9 ml sterile distilled water. This procedure was repeated to make serial dilutions of 10^{-1} to 10^{-8} (Houaghtby *et al.*, 1992).

3.5.3 Preparation of the media

All media (plate count agar, MacConkey agar, Brilliant green bile 2% Broth, Sabouraud dextrose agar or potato dextrose agar and Double layer

acetate agar) were obtained in a dehydrated form and stored in a hygroscopic environment in a cool dry place away from light and prepared according to the manufactures instructions.

3.5.4 Gram stain

With sterilized loop, a drop of water was placed on clean slide and mixed with a loop full of culture growth and spread to form a thin film. The film was allowed to air dry and fixed by flame, then stained with crystal violet for 30 seconds, washed, decolorized with 96% alcohol till the alcohol dripping from the slide showed faint colour, then rinsed with water and counter stained with safranin for 30 seconds and rinsed with water, blotted dry and examined under the oil objective (x100) (Richter and Vedamuthu 2003).

3.5.5 Culturing methods

3.5.5.1 Dilution methods

Five grams of the cheese were added to warm (45°C) 15 ml of 2% sodium citrate and blinded for 2 minutes. Then one ml from the mixture (cheese and sodium citrate) was transferred with sterile 1 ml graduated pipette to 9 ml sterile normal saline in a screw capped bottle and mixed thoroughly. Using another sterile pipette, 1 ml of the prepared dilution was transferred to the second dilution bottle. This process was repeated to make tenfold dilution from 10^{-1} to 10^{-8} (Richardson, 1985). Then 1 ml from each selected dilutions was cultured on duplicate culture containing 30-300 cfu were enumerated.

3.5.5.2 Examination of culture

Growth on solid media was examined visually with naked eyes for colonies appearance and changes in media.

3.5.6 Examination of bacteria

3.5.6.1 Total of bacteria (TBC)

The plate count agar medium was used for the determination of the total bacteria count according to Houghtby *et al.* (1992) and Ramakant (2006).

3.5.6.2 Preparation of the media

The medium was prepared by suspending 23.5 grams of powder in one liter of distilled water. Then boiled until dissolved completely and sterilized by autoclaving at 121°C at 15 pounds pressure for 15 minutes (Frank *et al.*, 1992).

3.5.6.3 Plating

From each dilution, 1 ml was transferred into sterile Petri dishes (duplicate) followed by addition of 15-18 ml melted plated count agar at 45-46°C, mixed thoroughly by rotating the dishes first in one direction and then in the opposite direction. When the medium has solidified, the dishes were incubated in an inverted position at 32±1°C for 48±3 hours.

3.5.6.4 Counting

Plates contain 25-250 colonies were selected and counted using colony counter. The number of colony-forming units (cfu) in each dilution was obtained by multiplying the number of colonies in reciprocal of each dilution.

3.5.7 Coliforms bacteria count

The count was performed according to Christen *et al.* (1992) and Marshall (1993) using MacConkey agar medium.

3.5.7.1 Preparation of the media

This medium was prepared by suspending 51.5 grams of powder in one liter of distilled water, then boiled until it dissolved completely and sterilized by autoclaving at 121°C at 15 pounds pressure for 15 minutes Christen *et al.* (1992).

3.5.7.2 Plating

From each dilution 1 ml was transferred into Petri dishes (duplicate) followed by addition of 15-18 ml melted, cooled medium (45-46°C) MacConkey agar medium, mixed thoroughly by rotating the dishes first in one direction and then in the opposite direction. When the medium was solidified, the dishes were incubated inverted position at 32±1°C for 24 ± 2 hours.

3.5.7.3 Counting

Plates containing 20-200 colony forming units (cfu) were selected and counted using a colony counter and the number of the colonies were obtained by multiplying number of colonies in each dilution by reciprocal of the dilution.

3.5.8 Lactic acid bacteria counts

Double layer acetate agar (Difco, 0742) was used for enumeration of lactic acid bacteria namely lactobacilli and streptococci. One ml sample decimal dilution was poured on the dried medium. The plates were inoculated into duplicates. The cultured plates were inoculated at 30°C for three days.

The colonies of lactic acid bacteria were observed between the layers of the medium. Their morphology and staining characteristics were studied by examination gram's stained smear (Harrigan and McCance, 1976).

3.5.9 Yeast and moulds count

Sabouraud dextrose agar medium was used for the enumeration of yeasts and moulds count to (Harrigan and McCance, 1976).

3.5.9.1 Preparation of the medium

This medium was prepared by suspending 65 grams of powder in one liter of distilled water, heated to boiling and sterilized in an autoclave at 121°C for one minute less than 15 pounds of pressure. Then the medium was left to cool to 45°C after that the medium was poured into sterile Petri-dishes (18-29 ml) and left to solidify.

3.5.9.2 Plating

For isolation, 0.2 ml portions of each samples decimal dilution 10^{-3} and 10^{-4} were streaked in duplicates on the dried medium. The plates were incubated at 30°C for 3 days. After 3 days, colonies of yeast and moulds were counted by colony counter and recorded. Total yeasts and moulds were calculated as the number of colony forming units per ml of samples (Harrigan and McCance, 1976). Yeasts cultures were also identified by microscope examination using gram's stain methods.

A sample for each dilution (0.2ml) was streaked on the medium. The sample was spread over the surface of the agar medium and the dishes were then inverted and incubated at 25-30°C for 3-5 days.

3.5.9.3 Counting

The plates contain 15-150 colony-forming units (cfu) were selected and counted using colony counter.

3.6 Sensory evaluation

Samples were judged by ten untrained panelists for colour, flavour, texture and saltiness using sensory evaluation sheet (Appendix 1) (Larmond, 1977).

3.7 Statistical analysis

Statistical analysis was done by using SPSS Program (version 16). general leaner model used in a factorial design to show the effect of Gum Arabic, fat levels and storage period on physicochemical and microbiological quality and sensory characteristics of cheese samples. Least significant differences (LSD) test was used for mean separation between treatments. The level of significance (0.05) was used in this study.

CHAPTER FOUR

RESULTS

4.1. Physicochemical and microbiological evaluation of cheese milk

The physicochemical characteristics of pasteurized milk and microbiological evaluation of cheese milk used in the present study were in Tables (1).

The results in these tables showed that the moisture content, total solid, ash, crude protein, fat, volatile fatty acid acidity and pH in the pasteurized milk were 89%, 10.3%, 0.86%, 3.78%, 3.7%, 5.74%, 0.21% and 6.4%, respectively. While in Table 3) the total bacteria count in the pasteurized milk was very low, 3.5×10^{-3} , while lactic acid detected in pasteurized milk.

4.2. Effect of different levels of Gum Arabic on the physicochemical characteristics of the Sudanese white cheese

Results in Table (2) showed that the effects of Gum Arabic on physicochemical characteristics of milk cheese.

The protein of cheese samples was significantly ($P < 0.05$) affected by the different levels of Gum Arabic among all treatments. The higher crude protein (26.09 ± 2.24) was recorded by the control cheese, while the lowest one ($23.66 \pm 3.22\%$) was recorded by the cheese with 0.75 Gum Arabic.

Table (1): Chemical composition and microbiological characteristics of raw milk

Moisture	Ts	Ash	Protein	Fat	V.F.A.	Acidity	pH	Total bacteria (cfu/ml)	Coliforms bacteria (cfu/ml)	Lactic acid bacteria (cfu/ml)	Yeast and moulds (cfu/ml)
89	10.3	0.86	3.78	3.7	5.70	0.21	6.4	103×2.5	ND	ND	ND

cfu = Colony forming units.

ND = Not detected

Table (2): Effect of different levels of Gum Arabic on physicochemical characteristics of the Sudanese white cheese

Gum Arabic level	Physicochemical characteristics					
	Protein (%)	Fat (%)	Total solid (%)	pH (%)	Tv FA (0.1N ml NaOH/100 mg)	Ash (%)
Zero	26.09±2.24 ^a	13.61±1.21 ^c	64.45±6.1 ^c	5.41±0.53 ^a	2.31±0.32 ^c	5.24±0.75 ^c
0.5	24.29±2.50 ^b	13.99±1.27 ^a	66.85±6.54 ^a	5.23±0.58 ^b	2.62±0.50 ^a	6.24±0.95 ^b
0.75	23.66±3.22 ^c	13.89±1.60 ^b	66.77±6.02 ^b	5.21±0.57 ^{cb}	2.41±0.32 ^b	6.48±0.72 ^a
L.S	***	***	***	***	***	***

Mean values bearing different superscripts within columns are significantly different (P<0.05).

L.S. = Levels of significance.

Fat contents of the cheese samples (Table 2) showed high significant differences ($P < 0.001$). The highest fat ($13.99 \pm 1.27\%$) was recorded in the cheese samples with 0.5% Gum Arabic while the lowest value ($13.61 \pm 1.21\%$) was found in the control cheese samples.

The results indicated that there was highly significant differences ($P < 0.001$) in the total solids content due to the treatments. The data illustrated that the highest total solids (66.85 ± 6.54) was in the cow's milk cheese with 0.5% Gum Arabic (Table 2) while the lowest one ($64.45 \pm 6.11\%$) was recorded in the control cheese.

Data in table (2) showed that there were highly significant differences ($P < 0.01$) in the pH of all treatments. The highest pH (5.41 ± 0.53) was in the cow's milk (3% fat) cheese without Gum Arabic, while the lowest one (5.21 ± 0.57) was in the cheese samples with 0.75 Gum Arabic.

Volatile fatty acids content of the cheese samples (Table 2) showed highly significant differences ($P < 0.001$) in all treatments, the highest VFA (2.62 ± 0.50 0.Nml NaOH/100 gram cheese) was in the cow's milk cheese with 0.5 Gum Arabic, while the lowest one (2.31 ± 0.32 0.1N ml NaOH/100 gm cheese) was in the control cheese.

The results (Table 2) demonstrated that highly significant ($P < 0.001$) variations were found in the ash content of the cheese samples in all treatments. The highest ash (6.48 ± 0.72) was in the milk cheese with 0.75 Gum Arabic while the lowest value (5.25 ± 0.75) was in control cheese.

4.3. Effect of different levels of Gum Arabic on the microbiological characteristics of the Sudanese white cheese

Results in Table (3) showed the effect of different levels of Gum Arabic on the microbiological characteristics of the Sudanese white cheese.

Total viable bacteria, lactic acid bacteria, coliform bacteria and yeast and moulds significantly ($P < 0.05$) affected by the different levels of Gum Arabic. The highest total viable bacteria count (2.70 ± 1.53 cfu/mg) was found in the control cheese, while the lowest one (1.65 ± 0.78 cfu/mg) was observed in the milk cheese with 0.5 Gum Arabic.

The highest lactic acid bacteria count (1.92 ± 1.53 cfu/mg) was observed in the milk cheese with 0.75 Gum Arabic while the lowest one (1.63 ± 0.55 cfu/mg) was found in the control cheese (Table 3). Also the highest yeast and moulds count (1.71 ± 1.16 cfu/mg) was found in the control cheese while the lowest one (1.22 ± 0.84 cfu/mg) was observed in the milk cheese with 0.5 Gum Arabic.

4.4 Effect of different levels of Gum Arabic on sensory characteristics of Sudanese white cheese

Result in Table (4) illustrated the main effect of different levels of Gum Arabic on sensory characteristics of Sudanese low fat cheese. Significant variations ($P < 0.05$) were found in the colour, flavor and texture, while no significant differences ($P < 0.05$) were observed in saltiness of cheese samples. The control cheese recorded the highest colour scores (6.08 ± 1.15), while the lowest one (5.15 ± 1.41) was for the cheese with 0.75% Gum Arabic. The best value for the flavor (5.36 ± 2.12) was in the control cheese, while the lowest one (4.16 ± 2.03) was in the cheese with 0.75% Gum Arabic.

The control cheese showed highest texture scores 4.40 ± 1.12 , while the lowest one 3.98 ± 1.91 was recorded in the cheese sample with 0.5% Gum Arabic. Non significant differences were observed in the saltiness in all treatments, the highest saltiness 4.50 ± 1.37 was found in the control cheese, while the lowest one 4.23 ± 1.28 was found in the cheese samples

Table (3): Effect of different levels of Gum Arabic on microbiological characteristics of Sudanese white cheese

Gum Arabic level	Microbiological characteristics			
	Total bacteria (log/cfu/gm)	Coliform bacteria (log/cfu/gm)	Lactic acid bacteria (log/cfu/gm)	Yeasts & moulds (log/cfu/gm)
Zero	2.70±1.53 ^a	1.29±0.81 ^a	1.63±0.55 ^c	1.71±1.16
0.5	1.65±0.78 ^c	1.07±0.73 ^c	1.64±1.01 ^b	1.22±0.84
0.75	1.74±1.10 ^b	1.25±0.85 ^b	1.92±1.53 ^a	1.27±1.01
LS	**	*	**	**

Mean values bearing different superscripts within columns are significantly different (P<0.05).

L.S. = Levels of significance.

Table (4): Effect of different levels of Gum Arabic on sensory evaluation of Sudanese white cheese

Gum Arabic level	Sensory characteristics			
	Colour (%)	Flavour (%)	Texture (%)	Saltiness (%)
Zero	6.08±1.15 ^a	5.36±2.12 ^a	4.40±2.12 ^a	4.50±1.37 ^a
0.5	5.20±1.39 ^b	4.48±1.83 ^b	3.98±1.92 ^c	4.23±1.28 ^c
0.75	5.15±1.41 ^c	4.16±2.03 ^c	4.27±1.27 ^b	4.44±1.20 ^b
L.S.	**	***	***	N.S.

Mean values bearing different superscripts within columns are significantly different (P<0.05).

L.S. = Levels of significance.

N.S. = Not significant.

with 0.5% Gum Arabic. The control cheese sample showed the highest scores in colour, flavor, texture and saltiness than other cheese samples with 0.5% and 0.75% Gum Arabic, respectively (Table 4).

4.5 Effect of storage period on physicochemical characteristics of the Sudanese white cheese

Data in Table (5) showed the main effect of storage period on physicochemical characteristics of Sudanese white cheese.

The protein content of the cheese samples was significantly ($P<0.05$) increased from 21.82 ± 3.49 at day zero to 25.47 ± 1.77 at day 120.

The ash content of the cow's milk cheese was affected significantly ($P<0.05$) by the storage period (Table 5). The highest ash content 6.99 ± 0.61 was observed at day 90, while the lowest one 5.60 ± 0.89 was at day zero.

The total solids content of Sudanese white cheese samples were significantly ($P<0.05$) increased from 59.29 ± 4.03 at day zero to 70.59 ± 5.86 at day 120.

The pH of the cheese samples (Table 5) showed was decreased significantly ($P<0.05$) with the advancement of the storage period. It was decreased from (5.90 ± 0.06) at day zero to 4.44 ± 0.14 at day 120.

Data in Table (5) showed that the total volatile fatty acids was not significantly ($P<0.05$) affected by the storage period it was decreased from 2.50 ± 0.67 at day zero to 2.34 ± 0.34 at day 120, while increase at day 60 to 2.64 ± 0.21 .

The fat content of the cow's milk cheese was affected significantly ($P<0.05$) by the storage period (Table 5). The highest fat content (14.39 ± 1.48) was found at day 90, while the lowest one (13.11 ± 0.84) was at day 60.

Table (5): Effect of storage period on physicochemical characteristics of the Sudanese white cheese

Storage period	Chemical composition					
	Protein (%)	Ash (%)	Total solids (%)	pH (%)	VFA (0.1N ml NaOH/100 mg)	Fat (%)
0	21.82±3.49	5.60±0.8 ^c	59.29±4.03	5.90±0.06 ^a	2.50±0.67 ^b	14.12±1.77 ^b
30	23.35±2.07	5.82±0.88 ^c	67.20±5.09 ^c	5.69±0.14 ^a	2.49±0.38 ^c	13.81±1.25 ^d
60	25.26±2.99	6.45±0.98 ^a	69.28±4.61 ^b	5.36±0.17 ^b	2.64±0.21 ^a	13.11±0.84 ^{cd}
90	25.48±1.96 ^b	6.99±0.61 ^b	66.01±4.95 ^d	4.85±0.28 ^c	2.46±0.29 ^{cd}	14.39±1.48 ^a
120	25.47±1.77	6.12±0.40 ^b	70.59±5.86 ^a	4.44±0.14 ^d	2.34±0.34 ^d	14.03±1.29 ^c
L.S	**	**	***	**	**	**

Mean values bearing different superscripts within columns are significantly different (P<0.05).

L.S.: Levels of significance.

NS: Not significance.

4.6 Effect of the storage period on microbiological characteristics of the Sudanese white cheese

Results in Table (6) illustrated the main effect of storage period on the microbiological quality of Sudanese white cheese. All the characteristics under investigation; total viable bacteria, coliform bacteria, lactic acid bacteria and yeasts and moulds counts were significantly ($P<0.05$) affected by storage period.

Total viable bacterial count of the cheese samples was significantly ($P<0.05$) decreased from $\log 2.05\pm 1.56$ cfu/mg at day zero to $\log 1.57\pm 0.96$ cfu/mg at day 90 and then increased to $\log 1.84\pm 0.67$ cfu/mg at day 120 of storage.

Coliforms count of the cheese samples were significantly ($P<0.05$) increased from $\log 1.46\pm 0.76$ cfu/mg at day zero to $\log 1.66\pm 0.58$ cfu/mg at day 30 and then decreased to $\log .7\pm 0.46$ cfu/mg at day 60 and it was not detected at day 120, (Table 6).

It was clear that in Table (6) the lactic acid bacterial count of the cheese samples decreased significantly ($P<0.05$) from 1.93 ± 1.44 cfu/mg at day zero to $\log 1.49\pm 1.10$ cfu/mg at day 120).

The results in Table (6) showed that yeasts and moulds of the cheese samples were significantly ($P<0.05$) increased from $\log 1.48\pm 0.79$ cfu/mg at day zero to $\log 2.04\pm 0.78$ cfu/mg at day 30 and then decreased to $\log 1.55\pm 0.60$ cfu/mg at day 90 and it was not detected at day 120 of the storage.

Table (6): Effect of storage period on microbiological characteristics of the Sudanese white cheese.

Storage period	Microbiological characteristics			
	TBC (cfu/gm)	Coliforms (cfu/gm))	Lactic acids bacteria cfu/gm	Yeasts and moulds (cfu/gm)
Zero	2.05±1.56	1.46±0.76	1.93±1.44	1.48±0.78
30	1.70±1.18	1.66±0.58	1.33±.56	2.04±0.88
60	1.59±1.03	1.17±0.46	1.67±1.55	1.47±.76
90	1.57±0.96	1.59±0.43	2.36±1.05	1.55±0.61
120	1.84±0.67	ND	1.49±1.10	ND
L.S	**	**	**	**

Mean values bearing different superscripts within columns are significantly different ($P < 0.5$).

L.S = Level of significance.

cfu = Colony forming units.

ND Not detected.

4.7 Effect of storage period on sensory characteristics of the Sudanese white cheese

Results in Table (7) showed the main effect of storage on sensory characteristics of the cheese samples. Results revealed that the best values for colour were recorded at day 60 (Table 9).

The colour scores of the cheese samples were affected significantly ($P<0.05$) by the storage period. The colour scores of the cheese samples increased from day zero up to the end of the storage (day 120). The highest value for the colour 5.97 ± 1.00 was recorded at day 60, while the lowest one 4.47 ± 1.43 was recorded at day zero.

Results in Table (7) showed that the flavor of the cheese samples was significantly ($P<0.05$) affected by the storage period. The flavor scores decreased from day zero up to day 120. The highest value 6.47 ± 1.43 for the flavor was at day zero, while the lowest one 2.17 ± 0.98 was recorded at day 120.

The texture of the cheese samples was significantly ($P<0.05$) affected by the storage period. The best value for the texture 6.54 ± 1.40 was scored at day zero, while the lowest one 2.56 ± 1.27 were recorded at day 90 (Table 7).

Saltiness of the cheese samples was significantly ($P<0.05$) affected by the storage period. The saltiness increased at day zero and thereafter decreased up to the end of the storage period. The highest value 5.51 ± 1.32 was found at day zero, while the lowest one 3.62 ± 0.98 was at day 120 (Table 7).

Table (7): Effect of storage period on sensory characteristics of the Sudanese white cheese.

Storage period	Sensory characteristics			
	Colour	Flavour	Texture	Saltiness
Zero	4.47±1.43	6.47±1.43	6.54±1.40	5.51±1.32
30	4.93±1.45	5.31±1.66	4.05±1.25	4.09±0.99
60	5.97±1.00	4.61±1.33	2.83±1.30	4.27±1.13
90	5.81±0.98	3.89±1.02	2.56±1.27	3.87±0.99
120	5.33±1.47	2.17±0.98	4.84±1.81	3.62±0.98
L.S	***	***	***	***

Mean values bearing different superscripts within columns are significantly different ($P < 0.5$).

L.S = Level of significance

4.8. Effect of different levels of fat on physicochemical characteristics of Sudanese white cheese

Results in Table (8) showed that the effect of different levels of fat on physicochemical characteristics of Sudanese white cheese. The results showed that there was significantly ($P<0.05$) variations in the protein content of the treatments. The data illustrated that the highest protein content 25.26 ± 3.12 was in the control cheese, while the lowest one 23.15 ± 2.51 was in the cheese made from 2% of fat.

Ash content of cheese samples was significantly ($P<0.05$) affected by the levels of fat. The highest ash content $6.22\pm .65$ was obtained in the cheese made from 2.5% of fat, while the lowest one 6.03 ± 1.03 was found in the control cheese.

Results in Table (8) showed that the total solids content were significantly ($P<0.05$) affected by the levels of fat. The highest one 66.85 ± 6.54 was recorded in the cheese made from 2.5% of fat, while the lowest one (64.45 ± 6.11) was obtained in the control cheese.

Data in Table (8) illustrated that the pH content not significantly ($P<0.05$) affected by the levels of fat. The highest pH content 5.41 ± 0.55 was found in the control cheese, while the lowest one 5.21 ± 0.57 was recorded in the cheese made with 2% of fat.

Volatile fatty acid content in Table (8) was significantly ($P<0.05$) affected by the levels of fat. The highest value of volatile fatty acid 2.61 ± 0.50 was found in the cheese made with 2.5% of fat. While lowest one 2.31 ± 0.32 was recorded in the control cheese. Fat content of cheese samples significantly ($P<0.05$) affect by the levels of fat. The highest fat content

Table (8): Effect of different levels of fat on physicochemical characteristics of Sudanese white cheese.

Storage period	Physicochemical characteristics					
	Protein (%)	Ash (%)	Total solid (%)	pH (%)	VFA (0.1N NaOH/100 mg)	Fat (%)
3%	25.26±3.12 ^a	6.03±1.0 ^c	64.45±6.11 ^c	5.41±0.55	2.31±0.32 ^c	13.61±1.20 ^c
2.5%	23.91±2.46 ^b	6.22±0.65 ^a	66.85±6.54 ^a	5.24±0.58	2.62±0.50 ^a	13.99±1.27 ^a
2.%	23.15±2.51 ^c	6.20±0.92 ^b	66.77±6.02 ^b	5.21±0.57	2.41±0.32 ^b	13.89±1.60 ^b
L.S.	**	*	**	N.S.	***	***

Mean values bearing different superscripts within columns are significantly different (P< 0.5).

L.S = Level of significance.

N.S.: Not significance.

13.99±1.27 was obtained in the cheese made with 2.5% fat, while the lowest one 13.61±1.20 was found in the cheese made with 3% of fat.

4.9. Effect different levels of fat on the microbiological characteristics of Sudanese white cheese.

Results in Table (9) showed that the effects of different levels of fat on the microbiological characteristics of Sudanese white cheese. The total viable bacterial count significantly ($P<0.05$) affected by the different levels of fat. The data illustrated that the highest total viable bacterial count 1.85±0.93 cfu/mg was obtained in the cheese made with 2% fat, while the lowest one 1.51±1.02 was found in the cheese made with 2.5% of fat.

Data in Table (9) observed that coliforms bacteria significantly ($P<0.05$) affected by the levels of fat. The highest coliforms bacteria count 1.28±0.86 cfu/mg was found in the cheese made with 3% fat, while the lowest one 0.99±0.67 cfu/mg was obtained in the cheese made with 2.5% of fat (Table 9).

Data in Table (9) illustrated that the lactic acid bacteria count significantly ($P<0.05$) affected by the levels of fat. The highest scores 2.24±1.52 cfu/mg was found in the cheese made with 3% of fat, while the lowest one 1.22±0.59 cfu/mg was obtained in the cheese made with 2.5% of fat.

Yeasts and mould count significantly ($P<0.05$) affected by the levels of fat. The highest scores 1.46±1.13 cfu/mg was obtained in the cheese made with 3% of fat, while the lowest one 1.00±0.74 cfu/mg was recorded in the cheese made with 2% of fat.

Table (9): Effect of different levels of fat on microbiological characteristics of Sudanese white cheese.

Fat levels	Microbiological characteristics			
	TBC	Coliforms	Lactic acid bacteria	Yeasts and moulds
3%	1.84±1.25 ^b	1.28±0.86 ^a	2.24±1.52 ^a	1.46±1.13 ^a
2.5%	1.51±1.02 ^c	0.99±0.67 ^c	1.22±0.59 ^c	1.38±0.85 ^b
2%	1.85±0.93 ^a	1.20±0.79 ^b	1.57±0.88 ^b	1.00±0.74 ^c
LS	**	**	**	**

Mean values bearing different superscripts within columns are significantly different (P< 0.5).

L.S = Level of significance

4.10. Effect of different levels of fat on the sensory characteristics of Sudanese white cheese

Results in Table (10) showed the effect of different levels of fat on the sensory characteristics of Sudanese white cheese. The results indicated that there were significant variations ($P < 0.05$) in the colour, flavor, texture and saltiness of the different cheese samples. The colour of the cheese samples significantly ($P < 0.05$) affected by the levels of fat. The highest value 5.90 ± 1.23 was obtained in the cheese made with 3% of fat.

Data in Table (10) illustrated that the flavor scores were significantly ($P < 0.05$) affected by the levels of fat. The highest score 5.03 ± 2.19 was found in the cheese made with 3% of fat, while the lowest one 3.97 ± 1.59 was obtained in the cheese made with 2% of fat.

Results in Table (10) showed that the texture of cheese samples significantly ($P < 0.05$) affected by the levels of fat. The highest value of texture (4.25 ± 1.95) was found in the cheese made with 2.5% of fat, while the lowest one (4.13 ± 1.98) was recorded in the cheese made with 2% of fat.

Saltiness in Table (10) was significantly ($P < 0.05$) affected by the levels of fat. The highest saltiness score 4.47 ± 1.29 was recorded in the cheese made with 3% of fat, while the lowest one 3.90 ± 1.06 was found in the cheese made with 2% of fat.

4.11. Effect of different levels of Gum Arabic and fat on physicochemical characteristics of Sudanese white cheese

Total crude protein of the cheese samples was significantly ($P < 0.05$) affected by the levels of Gum Arabic and fat. It was observed that the total crude protein contents increased with the Gum Arabic concentration (0.5) and decreased with the Gum Arabic concentration (0.75) and low-fat levels. As the fat levels the total crude protein contents increased in value. The

Table (10): Effect of different levels of fat on sensory characteristics of Sudanese white cheese.

Fat level	Sensory characteristics			
	Colour	Flavor	Texture	Saltiness
3%	5.90±1.23 ^a	5.03±2.19 ^a	4.13±2.12 ^b	4.47±1.29 ^a
2.5%	5.12±1.31 ^b	4.22±1.49 ^b	4.25±1.9 ^a	4.36±1.22 ^b
2%	4.60±1.36 ^c	3.97±1.59 ^c	4.13±1.98 ^c	3.90±1.06 ^c
L.S.	**	***	**	**

Mean values bearing different superscripts within columns are significantly different (P<0.5).

L.S = Level of significance

highest value 26.27 ± 1.03 was for the cheese with 3% fat and 0.5 Gum Arabic while the lowest one 22.99 ± 2.77 was found for the cheese made with 0.5% Gum Arabic and 2% fat (Table 11).

Result in Table (11) showed that ash content was significantly ($P < 0.05$) affected by the levels of Gum Arabic and fat. It was increased with the levels of Gum Arabic and fat. The highest ash content 6.63 ± 0.94 in cheese samples with 0.75 Gum Arabic with 3% of fat while the lowest one 5.24 ± 0.75 was found in the cheese.

Total solids contents of the cheese samples was significantly ($P < 0.05$) affected by the levels of Gum Arabic and fat levels. It was increased with both the levels of Gum Arabic and fat. The lowest total solids content 64.45 ± 6.11 was for content cheese (zero Gum Arabic, 3% fat) while the highest value 68.10 ± 7.56 was found for the cheese made with 0.5 Gum Arabic and 3% fat (Table 11).

Data in Table (11) showed that the pH content of the cheese samples which was significantly ($P < 0.05$) affected by the levels of Gum Arabic and fat. It was decreased with the levels of Gum Arabic and increased with the levels of fat. The highest pH (5.41 ± 0.53) was reported in the cheese samples made with 0% Gum Arabic and 3% fat, while the lowest one (5.14 ± 0.61) was found in the cheese samples made with 0.5 Gum Arabic and 3% fat.

Results in Table (11) showed yjy the volatile fatty acid content of the cheese samples was significantly ($P < 0.05$) affected by the levels of Gum Arabic and fat. It was increased with the increased levels of fat and decreased with the levels of Gum Arabic. The highest value (2.78 ± 0.42 0.1N ml NaOH/100 mg cheese) was found for the cheese samples made with 0.5 Gum Arabic and 3% fat, while the lowest one (2.00 ± 0.20 o.1N ml Na)H/100 mg) was found in the cheese samples made with 0.75 Gum Arabic (Table 11).

Table (11): Effect of different levels of Gum Arabic and fat on physicochemical characteristics of Sudanese white cheese.

Gum Arabic level	Fat level	Physicochemical characteristics					
		Protein (%)	Ash (%)	T.S. (%)	pH (%)	VFA (0.1N ml NaOH/100 mg)	Fat (%)
0	3%	26.08±09.09 ^b	5.24±0.75	64.45±6.11	5.41±0.53	2.31±0.32	13.61±1.21
0.5	3%	26.27±1.03 ^a	6.21±0.80	68.10±7.56	5.14±0.61	2.78±0.42	14.52±0.88
	2.5%	23.61±2.21 ^{cd}	6.35±0.79	64.83±5.72	5.26±0.58	2.38±0.42	13.86±1.39
	2%	22.99±2.77 ^{cd}	6.15±1.17	67.61±6.16	5.30±0.58	2.71±0.56	13.58±1.35
0.75	3%	23.43±4.38 ^{cd}	6.63±0.94	66.39±2.36	5.30±0.61	2.41±0.34	15.33±1.57
	2.5%	24.21±2.80 ^{cd}	6.01±0.47	64.41±8.51	5.17±0.48	2.00±0.20	13.83±0.97
	2%	23.32±2.30 ^{cd}	6.71±0.53	66.52±5.95	5.16±0.63	2.60±0.24	13.53±1.11
L.S		**	**	***	**	**	**

Mean values bearing different superscripts within columns are significantly different (P<0.05).

L.S.: Levels of significance.

Data in Table (11) showed that the fat content was significantly ($P<0.05$) affected by the levels of Gum Arabic and fat. It was increased with the levels of Gum Arabic and fat and decreased with the levels of Gum Arabic. The highest fat content 15.33 ± 1.57 was observed in the cheese made with 3% fat and 0.75 Gum Arabic, while the lowest one 13.53 ± 1.11 was found in the cheese made with 2% fat and 0.75 Gum Arabic.

4.12. Effect of different levels of fat and Gum Arabic on microbiological characteristics of Sudanese white cheese

Results in Table (12) showed that total bacteria count was significantly ($P<0.05$) affected by the levels of Gum Arabic and fat. It was decreased with the levels of Gum Arabic 0%, 0.5 and 0.75 with 3% fat and 3.5% of fat, while increased with the levels of Gum Arabic 0.5 and 0.75 Gum Arabic with 2% of fat. The total bacteria count was higher in the cheese sample made without Gum Arabic. The highest total bacteria (2.70 ± 1.54 cfu/gm) was found in the control cheese, while the lowest one (1.51 ± 1.09 cfu/mg) was recorded in the cheese samples made with 0.75 Gum Arabic and 2.5% of fat.

It is very clear that from results in Table (12) that the coliforms count significantly ($P<0.05$) affected by the levels of Gum Arabic and fat. The coliforms count increased with addition of Gum Arabic 0.5 and 0.75 with 3%, 2% of fat, while decreased in the cheese samples made from 0.5, 0.75 Gum Arabic with 2.5% of fat. The highest coliforms count 1.29 ± 0.81 cfu/mg was recorded for the control cheese, while the lowest one (1.03 ± 0.67 cfu/mg) was found in the cheese samples with 0.75% Gum Arabic and 2.5% fat.

Table (12): Effect of different levels of fat and Gum Arabic on microbiology characteristics of the Sudanese white cheese.

Fat level	Gum level	Microbiological characteristics			
		Total bacteria T.B.C. (cfu/gm)	Coliforms bacteria cfu/gm)	LAB (cfu/gm)	Yeasts and moulds (cfu/gm)
3%	0	2.70±1.54 ^a	1.29±0.81 ^a	1.63±0.55	1.71±1.16
	0.5	1.85±0.50 ^b	1.05±0.81 ^{cd}	1.46±1.33	1.38±0.81
	0.75	1.84±1.25 ^c	1.28±0.86 ^b	3.63±1.45	1.46±1.13
2.5%	0.5	1.58±1.13 ^{cd}	1.05±0.80 ^{cd}	1.21±0.76	1.51±0.97
	0.75	1.51±1.09 ^d	1.03±0.67 ^d	1.22±0.40	1.38±0.85
2%	0.5	1.52±0.63 ^d	1.10±0.65 ^c	2.25±0.54	0.76±0.55
	0.75	1.85±0.93 ^b	1.20±0.79 ^d	0.90±0.57	1.10±0.74
L.S		**	**	**	**

Mean values bearing different superscripts within columns are significantly different ($P < 0.05$).

L.S = Level of significance.

cfu = Colony forming units.

Data in Table (12) illustrated that lactic acid bacterial count was significantly ($P<0.05$) affected by the levels of Gum Arabic and fat levels. It was increased with the addition of Gum Arabic level 0.5 and 0.75 with 3% and 2.5% of fat, while decreased in the cheese samples made from 0.5 and 0.75 Gum Arabic with 2% of fat. The highest lactic acid bacteria count 3.63 ± 1.45 cfu/gm was recorded in the cheese samples made from 0.75 Gum Arabic and 3% fat, while the lowest one 0.90 ± 0.57 cfu/gm was found in the cheese samples made from 0.75 Gum Arabic with 2% fat.

Result in Table (12) showed that the yeasts and moulds count were significantly ($P<0.05$) affected by the levels of Gum Arabic. 0.5 and 0.75 with 3% and 2% of fat, while decreased with the levels of Gum Arabic in cheese samples made 0.5 and 0.75 Gum Arabic with 2.5% of fat.

The lowest yeast and moulds counts (0.76 ± 0.55 cfu/mg) was recorded in the cheese samples made from 0.5 Gum Arabic with 2% of fat, while the highest one 1.71 ± 1.16 cfu/gm was found in the control cheese.

4.13. Effect of different levels of Gum Arabic and fat on sensory characteristics of Sudanese white cheese

Data in Table (13) indicated that colour, flavor, texture and saltiness was significantly ($P<0.05$) affected by the different levels of Gum Arabic and fat. Colour of the control and cheese samples made from 0.5 and 0.75 Gum Arabic with 3% of fat decreased, while in cheese samples made from 0.05 and 0.75 Gum Arabic with 2.5% and 2% of fat was increased. The best colour 6.08 ± 1.15 was recorded in the control cheese, while the lowest one 4.60 ± 1.33 was obtained in the cheese samples made from 0.5 Gum Arabic with 2% of fat.

Table (13): Effect of different levels of fat, Gum Arabic on sensory characteristics of the Sudanese white cheese.

Fat level	Gum Arabic	Sensory characteristics			
		Colour	Flavour	Texture	Saltiness
3%	0	6.08±1.15 ^a	5.36±2.21 ^a	4.40±2.12 ^a	4.50±1.37
	0.5	5.92±1.25 ^b	5.04±2.09 ^b	3.74±1.94 ^d	4.40±1.46
	0.75	5.90±1.23 ^b	5.03±2.19 ^b	4.13±2.12 ^c	4.47±1.39
2.5	0.5	5.08±1.27 ^c	4.38±1.72 ^c	4.16±1.93 ^c	4.36±1.24
	0.75	5.12±1.31 ^c	4.22±1.69 ^c	4.25±1.95 ^b	4.36±1.22
2%	0.5	4.60±1.33 ^d	4.02±1.49 ^c	4.04±1.90 ^c	3.94±1.08
	0.75	4.60±1.36 ^d	3.97±1.57 ^d	4.13±1.98 ^c	3.90±1.06
L.S		**	***	**	***

Mean values bearing different superscripts within rows are significantly different (P<0.5).

L.S = Level of significance.

Results in Table (13) showed that flavor of the cheese sample was significantly ($P<0.05$) affected by the levels of Gum Arabic and fat. Its decreased in the most samples with addition of Gum Arabic and different level of fat.

The best flavor 5.36 ± 2.72 was obtained in the control sample, while the worst one 3.97 ± 1.57 was recorded in the cheese sample made from 0.75 Gum Arabic with 2% of fat. Cheese made without Gum Arabic obtains the highest values for the flavor compared with that made from 0.5% and 0.075% Gum Arabic and low levels of fat respectively.

Texture of the cheese samples was significantly ($P<0.05$) affected by the different levels of Gum Arabic and fat (Table 13). The control cheese showed the highest value for texture compared with that made from 0.5% and 0.75% of Gum Arabic and fat levels, respectively. The highest texture 4.40 ± 2.12 was recorded in the control sample, while the lowest one 3.74 ± 1.94 was found in the cheese made from 0.5% Gum Arabic with 3% of fat.

In Table (13) saltiness of the cheese samples was significantly ($P<0.05$) affected by the different levels of Gum Arabic and fat. Saltiness decreased with the addition of Gum Arabic with the levels of fat 2.5% and 2%, while increased with the addition of Gum Arabic with 3% of fat.

The highest saltiness (4.50 ± 1.37) was found in the control cheese, while the lowest one (3.90 ± 1.06) was recorded in the cheese made from 0.75 Gum Arabic with 2% of fat.

CHAPTER FIVE

DISCUSSION

Total solids of the cheese samples decreased with the increasing levels of Gum Arabic (Table 2). This could be attributed to the high moisture content in the cheese made from different levels of Gum Arabic. These results were in line with those reported by Lakovchenk and Arsenva (2016) who studied Tapioca Maltodextrin in the production of soft unripened cheese and reported that the total solids increase in cheese curds made from ultrafiltration concentrate of skimmed milk with tapioca maltodextrin led to an increase in moisture-binding capacity in sample with adding maltodextrin tapioca as compared with the samples without the additive. The results of this study was agreed with those reported by Dhoul and Hamid (2013) who studied the physicochemical and sensory characteristics of white soft cheese made from different levels of cassava powder (*Manihot esculenta*). They mentioned that total solids decreased with the levels of cassava powder milk. The total solids found in this study were in line with those reported by Birader *et al.* (2012) who studied the effect of different levels of soybean milk (10, 20, 40 and 50%) on the chemical composition of cheese made from buffalo milk and found that total solids decreased with the levels of soybean milk. Also these results were coincided those of Nazim *et al.* (2013) and Rinaldoni *et al.* (2014) who reported that the total solids content were lower in a cheese made from soybean compared to that made from cow milk. Similar results were also recorded by Billal (2000) who studied that the chemical composition of a Sudanese white cheese

affected by different levels of soybean milk (5, 10 and 15%) and he stated that total solids decreased with the levels of soybean milk.

The total solids found in this study were within the range of the total solids given by Suliman *et al.* (2013) and Hamid (2014) who studied the effect of cumin oil concentration on chemical composition and sensory characteristics of Sudanese white cheese during ripening and he stated that the total solids contents of the cheese sample with 0.1% cumin oil was significantly ($P < 0.001$) higher than that of the control cheese samples.

Fat contents of the cheese samples increased with low levels of Gum Arabic and decreased with high level of Gum Arabic compared with that made without Gum Arabic (control) (Table 2). These results were in line with those used seven varied levels of the Bambar nut milk (5, 10, 15, 20, 30, 40 and 50%) in the manufacturing of the Nigerian Wareankashi white soft cheese and reported that fat decreased with the levels of the Bambar nut milk (Yakubu and Amuzat, 2012). These results were in line with those reported by Esmail *et al.* (2010) who used three concentration of Gum Arabic (0.25, 0.50 and 0.75% per each kilogram of milk) to manufacture the Iranian Sudanese white cheese and revealed that fat contents increased with the levels of Gum Arabic. Our results were similar to those of Abdel Razig and Sewayleh (2009) who showed that fat content of labneh cheese increased with levels of skim milk powder. The results in this study were in accordance to the work of Oladipo and Jadesirii (2013) who reported that fat was higher in the cheese made from garlic in West Africa soft cheese.

Results in Table (2) illustrated that protein decrease with the levels of Gum Arabic. These results could be due to the effect of Gum Arabic and heat treatment which resulted in denaturing of whey protein and their

reduction in cheese curd. It could be due to the low amount of the protein in Gum Arabic. These results were confirmed by Alnemr *et al.* (2013) who used enhanced technological texturizing inulin to improving of Karish cheese and the reported that TN and protein content of cheese were significantly ($P < 0.05$) affected by inulin. The control cheese had higher values of TN and protein as compared with those made with inulin.

The results in this study were different from those of Elhassaneen *et al.* (2013) who stated that the protein content of cheese samples with cumin oil concentration were higher than that of the control cheese without cumin oil. Also the results in this study were disagree with those reported by Hamid (2014) who studied the effect of cumin oil concentration on chemical composition and sensory characteristics of Sudanese white cheese during ripening and stated that crude protein contents increased significantly ($P < 0.05$) as cumin oil concentration increased. These results were in accordance with those found by Pinar and Mustafa (2011) who mentioned that protein was lower in fresh Kashar cheese of Turkey produced from soybean protein.

The results were disagreed with those reported by Dhoul and Hamid (2013) who found that protein increased with the level of cassava powder milk. Also these results was not in accordance with those found by Rajaj *et al.* (2014) who found that protein increased with the levels of soybean milk.

Results in Table (2) showed that the pH of the cheese samples decreased with the levels of Gum Arabic. The decreased of the pH could be due to the increased of the moisture content or increased of the acidity. These results were in harmony with those of Gulzar *et al.* (2015) who

studied that the nutritional and functional properties of fruited cream cheese spread as influenced by hydrocolloid and they reported that pH play an imported role in giving the texture of the product. The pH of treated samples did not differ significantly with the change of hydrocolloids and the pH decreased. These results also agree with those reported by Lakovchenko and Arsenva (2016) and he found that pH-value of cheeses made from ultrafiltration concentration of skim milk showed no significant difference with the use of different tapioca maltodextrin concentration. Although, it had a tendency of a decrease pH-value with the increase of the maltodextrin concentration.

Volatile fatty acids of the cheese samples increased with the level of Gum Arabic (Table 2). This increase could be attributed to fact that adding of Gum Arabic to milk cheese inhibits some microbial enzymes. The increased of the volatile fatty acids with the levels of Gum Arabic could be also due to decrease of the pH-values. These results were similar from those obtained by Dhoul and Hamid (2013) who reported that there were significant differences ($P < 0.05$) in the total volatile fatty acids between all the treatments. The highest total volatile fatty acids (2.62 ± 0.50 0.1Nml NaOH/100 gms cheese) was in the cow's milk cheese with 0.5 Gum Arabic while the lowest one (2.31 ± 0.32 0.1N ml NaOH/100 mgs cheese) was in the cow's milk cheese without Gum Arabic. These results were disagreed with those reported by Khalifa *et al.* (2015), who stated that the cheese samples which treated with dehydrated cranberry fruit extract powder had showed lower significant ($P < 0.05$) total volatile fatty acids content than the control cheese samples.

Ash content of cheese samples in this study increased with the levels of Gum Arabic (Table 2). This could be attributed to the high nutrient and mineral contents of Gum Arabic. The increased of the ash content could also be due to the absorption of salt by curd. This findings were in line of those Dhoul and Hamid (2013) who studied physicochemical and sensory characteristics of white soft cheese made from different levels of cassava powder and stated that the highest ash (6.38 ± 0.46) was in the cow's milk cheese with 1% cassava, while the lowest ash in the cow's milk cheese with 0.5% cassava. Similar increased of ash was reported by Hamid and Abdelrahman (2012) during the chemical analysis of the cheese made with cardamom, cinnamon and fenugreek goat's milk.

The values of the ash found in this study were higher than that obtained by Yakuba and Amuzat (2012) who reported that ash contents of Tofu cheese produced in Northern part of Nigeria was about $3.30\pm 1.82\%$. These results were not in line with those of Abdual-Rahaman (2013) who reported that ash content was lower in the cheese made with safflower seed extract.

The total bacterial count of the cheese samples in this study increased with increasing levels of Gum Arabic (Table 3). Total bacteria of the cheese made from Gum Arabic were lower compared with that made from milk without Gum Arabic. This could be attributed to the fact Gum Arabic has reduced the value which leads to decrease of the microbiological load of the cheese made from different levels of Gum Arabic. Similar results were recorded by Miocinovic *et al.* (2014) who studied the properties of low-fat ultrafiltered cheese produced with probiotics bacteria and they stated that at the beginning of the study period, the number of bifidobacteria was significantly lower than the number of *L. acidophilus*, probably due to the

ratio of these two strains used in the commercial starter culture. These results were in agreement with those of Badawi *et al.* (2009) who demonstrated that total bacteria counts decreased with the levels of *Nigella sativa* and their results were supported by Alsawaf and Alnaemi (2011) who used two levels of *Nigella sativa* seeds (1% and 3%) to study some poisoning and pathogenic bacteria of the Sudanese white soft cheese made from ewes milk and they reported that total bacterial counts decreased with levels of *Negella sativa* seeds that inhibited the microbial growth including the total bacterial count.

Total bacterial count in this study was not in line with those reported by Dhoul and Hamid (2014) who used different levels of cassava powder to manufacture Sudanese white soft cheese and they demonstrated that total bacterial count was higher in the cheese made with cassava powder compared to that made without cassava powder. These results supported by Kheir *et al.* (2011) who used *Solanumn dubium* fruit extract to manufacture Sudanese white soft cheese; they reported that total bacteria counts were higher in the cheese made with *Solanum dubium* compared to that made with rennet.

In Table (3) the total coliforms counts increased with the levels of Gum Arabic. Coliforms can metabolize the high acidity and low pH of the cheese made from Gum Arabic and it can grow normally. These results were in disagreement with those of Ali (2012) who stated that coliforms were not found in a lebenh cheese made from different levels of skim milk powder. These results are the same to that obtained by Dhuol and Hamid (2014) who showed similar effect of cassava powder on coliforms of Sudanese white soft cheese. On the other hand these results were in

disagreement with those of Badawi *et al.* (2009) who revealed the coliforms counts decreased with different levels of *Nigella sativa* levels. Also our results were in disagreement with those of Abdel-Razig and Babiker (2009) who did not recorded any coliforms in cheese made with acidifying agents. The values recorded for coliforms in this study were higher from that reported by Nazar *et al.* (2012) when they collected ten samples of Sudanese white soft cheese and reported that coliforms ranged from 0.0 to 1.00 cfu/mg.

Results in Table (3) indicated that lactic acid bacteria increased with the levels of Gum Arabic. The increased of lactic acid bacteria with the levels of Gum Arabic could be attributed to the fact that Gum Arabic has additional nutritive value which is leads to the increased of microbiological load of the cheese made from different levels of Gum Arabic. Similar results were obtained by Kheir (2011) who reported that lactobacilli and streptococci were both higher in the cheese made with *Solanum dubium* compared to that made with rennet. These results were not in accordance with those of Adam (2011) who used five levels of black cumin seeds to manufacture the Sudanese white soft cheese and he recorded that lactic acid bacteria decreased with the levels of black cumin.

Yeast and moulds count in the cheese samples (Table 3) decreased with the levels of Gum Arabic. This decrease could be attributed to some antimicrobial materials in Gum Arabic which inhibited the growth of yeast and moulds. These results were in line with those of Dhoul and Hamid (2014) who reported that yeasts and moulds decreased when they used different levels of cassava powder (0.5, 0.75 and 1%) for cheese manufacture. These results was in accordance with that reported by Nour El

Daim *et al.* (2006) who stated that yeasts and moulds decreased when they used two different levels of fat (2.2 and 4.4%) of cheese manufacturing. These results were in disagreement with those of Amer (2008) who used three acidifying agents for manufacturing of Ricotta cheese and he did not find any yeasts and moulds in the different Ricotta cheese samples.

Results in Table (4) showed that cheese made from milk without Gum Arabic recorded the highest values for colour and texture, while the best values for flavour in cheese made with 0.5% Gum Arabic revealed 4.48 ± 1.83 . By mean that cheese from milk without Gum Arabic and the samples that made from milk, the 0.75 Gum Arabic recorded the highest values for the sensory characteristics. This could be attributed to properties of Gum Arabic which change the sensory characteristics of the cheese specially colour, flavour and texture, while most of the consumers (panelist) prefer the cheese with white colour, good flavour and texture which were very clear in the cheese made from milk without Gum Arabic.

These results were in line with those of Naser and Hamid (2016) who used two types of milk (fresh cow milk and fresh goat milk) to manufacturing white soft cheese made from sunflower (*Helianthus annuus* seeds enzyme) they stated that the colour and flavor of the white cheese was significantly ($P < 0.05$) affected by milk sources. Moreover, saltiness of the cheese was significantly ($P < 0.05$) affected by milk sources, while milk sources was not significantly ($P < 0.05$) affected the texture of while cheese.

The present results were in line with those of Billal (2000) who used varied levels of soybean milk to manufacture a Sudanese white soft cheese and she reported that sensory characteristics decreased with the levels of soybean milk.

The results in this study were not in line with those obtained by Hamid (2014) who studied the effect of cumin oil concentration on chemical composition and sensory characteristics of Sudanese white cheese during ripening. He reported that the colour and texture of the cheese samples were not significantly ($P < 0.05$) affected by cumin oil concentration. However, the flavor and taste of the cheese were significantly ($P < 0.001$) affected by cumin oil concentration. The highest flavor scores were recorded for the cheese samples with 0.3% cumin oil while the lowest one was for the control cheese. Similarly the results with those obtained by Okorie and Adedohum (2013) who stated that sensory characteristics were improved in the cheese made from different levels of Bambar nut milk. These results were also different from those reported by Biradar *et al.* (2012) who reported that sensory characteristics were improved in the Indian fresh white cheese made from different levels of soybean milk.

Results in Table (5) illustrated that crude protein contents of the cheese samples increased with the storage period. This increase could be attributed to the moisture content of cheese samples. These results were in line with those of Hamid (2014) who reported that as the storage period progressed the protein content of cheese samples significantly ($P < 0.05$) increased. This result agreed with those of Hamid and Abdelrahman (2012); Moahmed (2011); Hamid (2005); Abdel Razig (1996) and Kur (1992) who showed that the protein content of cheese increased during ripening due to decrease in moisture contents. However, results in this study were not in line with those of Dhoul and Hamid (2013); Abdel-Razig and Babiker (2009); Bilal (2000); Abdalla (1992); Khalid (1991) and Nuser (2001) who found that protein decreased during the storage. Nofal *et al.* (1981) explained that the protein content decreased during the storage period due to the degradation

of protein and loss of pickling whey. Nuser (2001) found that the decreased in protein contents during pickling was a direct results of protein degradation leading to the formation of water-soluble compounds which were lost in the pickling solution leading to increase in the nitrogen contents of the whey.

Ash contents of the cheese samples in this study increased with the storage period (Table 5). Increased in ash content may be due to the decreased in moisture content and absorption of salt by curd (Abdalla and Abdel Razig, 1997). These results coincided with those obtained by Hamid (2014); Abdalla *et al.* (2011) who found that the ash contents of Sudanese white soft cheese increased during the storage period. Moreover, Hamid (2014) stated that the high ash content of the cheese samples with cumin oil concentration could be due to preservation effect of the cumin oil on the cheese component, also these results were in line with those reported by Ramadan (2007) and Hassanein *et al.* (2004). Similar results were obtained by Dhoul and Hamid (2015) who revealed that ash contents of cassava powder white soft cheese increased with the storage period. However, these results were not in line with those obtained by Abdalla *et al.* (1993) who stated that ash contents decreased and remained constant throughout the storage time.

Total solids of cheese samples increased during the storage period (Table 5). This increased could be attributed to decrease in the moisture content as the results of lactic acid developments which caused curd contraction (Hamid, 2014). Similar results were obtained by Osman (2008); Abdalla *et al.* (2011) who reported that total solids of the Sudanese white soft cheese increased during the storage period. Aly and Galal (2002) stated that the increased of the total solids content of the cheese up to day 120 was

likely attributed to continuous loss of moisture from cheese (El Onwi and Hamid, 2008). These results were different from those of Suliman *et al.* (2013) who reported that the levels of total solids were decrease in all cheeses during the storage period. Their results have been supported by Nour El Diam and El Zubeir (2010) who found that the total solids content of the Sudanese white cheese were 41.58% and 50.32% for 2.2% and 4.4% fat milk, respectively. They also added that the different fat percent and storage periods showed significant differences ($P < 0.05$) on the total solids for Sudanese cheese. Similarly Romeih *et al.* (2002) reported that the total solids of white –brined cheese decreased and the casein fat ratio increased as the fat content in the milk.

The pH of the cheese samples (Table 5) decreased till the end of the storage period. This might be attributed to the fact that storage at 4°C in refrigerator tends to decreased titratable acidity which leads to a decreased in pH values. Alnemr *et al.* (2013) reported that Karish cheese manufactured without inulin had the lowest pH value, especially at the end of storage period. In addition it could be noticed that the pH values of all cheeses gradually decreased during the storage period. These results were not in accordance with work of Alnemer *et al.* (2015) who stated that pH results of processed cheese trials made with different substitution levels of milk protein replacer during storage period was higher than control in the beginning and end of storage period. As pH values and dry matter content enables comparing the effect of different concentration of milk protein replacer used because both pH and dry matter influence the consistency of processed cheese. Similar results that observation by Gulzar *et al.* (2015) who reported that the pH and acidity of treated samples did not differ significantly with the change of hydrocolloids, while pH decrease and

acidity increase with storage period. Similarly, Hatem *et al.* (2012) reported that pH values progressively decreased during storage period. Our results were also supported of those of Sheehan *et al.* (2009) who observed that a decrease in the pH values of semi-hard cheeses manufactured from a mixture of caprine and bovine milk during 150 days of cold storage. Ali and Abdel Razig (2011) stated that the increase of pH values could be due to an increased acidity which activated by the natural microflora of raw milk as the result of lactose fermentation which lead to increase the pH value.

Results in Table (5) showed that volatile fatty acid increased significantly ($P < 0.05$) at day 60 of storage period. This indicated that the level of lipolysis was positively correlated with cheese adding. These results are similar to those observed by Ihsan *et al.* (2011) who studied the effect of different brine concentrations and ripening period on some quality properties of Turkish white pickled cheese and they stated that the acid degree value levels of all the cheese increased significantly ($P < 0.05$) after 30 days of storage. The increase of the volatile fatty acid probably could be attributed to the rapid lipolysis in fats at high temperature. Lipolysis results in the formation of free fatty acids, which is constituents of cheese, flavour (Perotti *et al.*, 2005). However, volatile fatty acids at the refrigerator temperature were attributed to suppression of lipolytic agent by the low storage temperature. These results were not in consistent with those of Kondyli *et al.* (2002) who reported that the low fat cheese had higher total volatile fatty acid levels, significantly ($P < 0.05$) increase of volatile fatty acids of cheese during the storage period. Their results supported by Hayaloglu *et al.* (2005). Similar results were obtained by Hatem *et al.* (2012) who stated that total volatile fatty acid increased with the storage period in Ras cheese of the Mediterranean countries. Our findings were not

in accordance with those of Dhuol and Hamid (2013) who used varied levels of cassava powder milk to manufacture the Sudanese white soft cheese and they demonstrated that volatile fatty acid increased with the storage period in a Sudanese white soft cheese made from cassava powder milk.

Fat contents of the cheese samples decreased from day zero of the storage time up to 60, then increased at day 90 and 120 of storage period (Table 5). the decreased of fat contents could be explained by the degradation of the total fat, dissolution of salt and fat into the pickling solution or absorption of whey by curd (Nuser, 2001). Other results demonstrated that the decreased in fat content was probably due to the lipolytic activity of microorganism on fat resulting in leakage of some fat from curd into the pickling whey (Dariani *et al.*, 1980). The decreasing values for all cheeses in fat content during the storage period also supported Abdalla and Mohamed (2009) who found significant reduction in fat during advancement of storage period. These results confirmed the findings of Hamid and Abdelrahman (2012); Abdalla *et al.* (2011) who demonstrated that fat content of the Sudanese white soft cheese decrease with storage period. The findings in this study agreed with those of Khalid (1991) and Nuser (2001) who reported that there was decrease in fat content during storage period. This results were in line with those reported by Farbod *et al.* (2013); Abdalla *et al.* (2011).

The data in Table (6) illustrated that total bacterial count decreased with the storage period from day zero up to day 90 and then increased at day 120 of storage. The decreased of total bacterial count during the storage period could be attributed to lactic acid production. While the increased of total viable bacteria in the end of the storage period may be attributed to

microbial load in raw milk used in manufacture cheese samples. These results were in accordance with those of Kheir *et al.* (2011) who reported that total bacterial count decreased with the storage period from first day up to day 90 in white soft cheese made from *Solanum tuberosum* extract and rennet. Similar obtained by Aly and Galal (2002) who stated that the total bacterial count was decreased when Damiaty cheese made from raw milk when stored for four months.

These findings were not in agreement with those of Dhuol and Hamid (2014) who stated that total bacterial count increased with storage period from day zero up to day 60 of storage and these could be attributed to rapid growth of microorganisms, while the decreased in day 90 may be attributed to lactic acid production. These results also were not as obtained by Nour El-Daim and El Zubeir (2006) who stated that total bacterial count increased during the storage period. These results were not in line with those of Abdel Salam (2012) who reported that total bacterial count increased with storage period up to day 60 and then decreased. Significantly increased in total bacterial count of the cheese samples was observed by Abdalla *et al.* (2012) who studied the total bacteria count of a Sudanese white soft cheese stored in five different containers and stated that bacteria count increased from day zero up to day 75 of the storage period and then decreased. Our results were also disagreement with those of Ahmed and Alhassan (2010) who recorded that total bacteria count increased with the storage period from day zero up to day 84 and then decreased. These results were not in the same line with those of Ceylon *et al.* (2003) who found that the total bacterial count of the cheese samples increase during storage period due to microbial count of raw milk.

Results in Table (6) showed that coliforms count increase at day 30 of storage period, decrease at day 60 and then increased at day 90 and completely disappeared. These could be due to the decreased of the pH of the cheese as stated by the Dhuol and Hamid (2014). These results were in accordance with the work of Abdalla *et al.* (2012) who reported that the coliforms count of Sudanese white soft cheese stored in five different containers, they found that the coliforms decreased from day zero up to the day 180 of the storage period and not detected in some containers from the day 120 of the storage period. These results were also in line with the results of Nour El-Daim *et al.* (2006) who reported that the heat treatment and processing improve the cheese quality via reducing the counts of coliforms which is significantly decreased with storage period. These results were also in harmony with the results of Alnemr *et al.* (2015) who realize similar decreased of coliforms in a low fat cheese. These results were also in line with those of Zekei *et al.* (2004) who recorded that coliforms count decreased with the storage period up to day 30 and then did not detected at the day 60 and 90 of the storage period.

Data presented in Table (6) illustrated that the lactic acid bacteria decreased with the storage period. The decreased of lactic acid bacteria could be attributed to the low temperature of ripening period. These results were in line with those of Reale *et al.* (2016) who studied the effect of reparative and catalase-positive *Lactobacillus cassei* adjunct on the production and quality of cheddar-type cheese and they stated that as in previous studies cultivable lactococcal population decreased during the ripening with the same trend in all cheeses, suggesting that the adjunct cultures did not affect growth and survival of starter culture (Fitzsimon *et al.*, 2001); Milesi *et al.*, 2008a). These results were in line with those of

Torracca *et al.* (2016) who stated that after 2 months of ripening, microbial counts of samples of cheese made with the raw milk were significantly higher than those of samples done with pasteurized milk. Regarding the results at the end of ripening period, no statistically significant differences were found for Entero-bacteriaceae, which were detected only in 3 samples, all cave-ripened (2PC and 1RC samples) milk pasteurization had a significant effect on enterococci counts with higher microbial counts in raw milk cheese samples at the end of the ripening period. For lactobacilli after 4 months of ripening, PF samples had significantly lower microbial loads compared with the other 3 types of samples. These results coincided with those of Miocinovic (2014) who studied the properties of low-fat ultra-filtered cheeses produced with prebiotic bacteria. He stated that at the beginning of the study period, the number of bifidobacteria was significantly lower than the number of lactoacidophilus probably because of ratio of these two strains used in the commercial starter culture. During the ripening period, the significant reduction in their number was found at the end of investigated ripening period ($<10^{-7}$ cfu/g-1) probably due to their sensitivity in the low-pH values. These findings were in line of Alnemr *et al.* (2013) who reported that the changes of viable count of starter bacterial during the storage period of Karish cheese supplemented with texturized inulin are present in the viability of total bacteria count with texturized prebiotic inulin during storage period exhibited higher counts than control. The results of the present study were consistent in qualitative terms with those reported by Martinez *et al.* (2006) who reported significantly higher retention of viability of lactic acid bacteria were grown in the presence of prebiotic compared with the control without prebiotic.

Yeasts and moulds count of the cheese samples (Table 6) were significantly increased at day zero up to day 90 of storage period and then were not detected at day 120 of the storage. The increased of yeasts and moulds during storage period might be due to the fact that yeasts and moulds could metabolized the lactic acid and low pH value (Nour El-Daim and El Zubeir, 2006). These findings supported by the results of Abdalla *et al.* (2012) who studied the yeasts and moulds count of Sudanese white soft cheese stored in five different containers. They found that yeasts and moulds were significantly increased from the day zero up to the day 75 of the storage period. However, El Onwi and Hamid (2009) reported that yeasts and mould were detected only at day zero in the cheese stored in anti-acid can (2.65 ± 0.48 log cfu/ml), while the two organisms increased in numbers in samples kept in plastic containers at day 60 then gradually decreased to 1.74 ± 0.14 log cfu/ml at day 240.

Results in Table (7) illustrated that there were significance change ($P < 0.05$ in all the characteristics under investigation (colour, flavour, texture and saltiness) during the storage period. The results showed that the colour of cheese samples was increased significantly from day zero up to end of storage period, while the flavour, texture and saltiness were decreased gradually with the storage period. These results were in line with those reported by Gulzar *et al.* (2015) who found that highly significant variation with storage, treatments and interaction of storage and treatments on butter flavour of FCS. Maximum butter flavour (4.1 score) was found in CSGP and lowest sensory score 1.9 was found in CSP. Butter flavour increased as storage period increased. The results in flavour, texture and saltiness was confirmed the results of Dhuol and Hamid (2014) who revealed that there were significant changes in a colour, flavour and texture

of the Sudanese white soft cheese made from cassava powder during the storage period. However, the flavour, texture and saltiness were decreased gradually with storage period. These results supported the results obtained by Hamid *et al.* (2012) who demonstrated that sensory characteristics of the cheese samples decreased with the storage period and this could be due to proteolytic processes occurred during storage period. These results were in line with those of Rahimi *et al.* (2007) who studied the texture of low-fat Iranian white cheese as influenced by gum tragacanth as a fat replacer and they stated that the supplementation of low fat milk with Gum tragacanth resulted in a marked increase in whiteness.

These results were in line with those of El Onwi and Hamid (2008) who reported that there were significance changes during the storage in a colour, flavour and texture of the Sudanese white soft cheese. However, the colour, flavour, texture and saltiness were decreased gradually with storage period. These results were in accordance with the results of Nour El Daim *et al.* (2007) who studied the yield and sensory evaluation of the processed cheese from Sudanese white cheese. These results obtained by Hussein (2004) who reported that sensory characteristics of the cheese decrease with the storage period.

The result in present study was in disagreement with the work of Mohamed (2011) who demonstrated that all the sensory characteristics of the cheese increased during the storage.

The best scores for colour, flavour and texture were obtained at the first day of the storage period, while the highest values for the saltiness were recorded at day 60. These results were in contradicted the findings of Nuser (2001) who reported that storage period did not affect the colour of

Sudanese white cheese during storage for 45 days. Moreover, El Naz *et al.* (2014) found that the best values for the sensory characteristics of the Kurdish cheese were obtained at the second month of the storage time.

Total crude protein of the cheese samples increased with the levels of Gum Arabic and decreased with the levels of fat (Table 6). These results were in line of those reported by Suliman *et al.* (2013) who studied the effect of milk fat level on the compositional quality of Sudanese white cheese during storage they found that the level of protein was affected significantly ($P < 0.05$) by fat content. This results were also in accordance with those reported by Karaman *et al.* (2013) who studied the improving quality characteristics of reduced and Turkish white cheeses using homogenized cream they reported that protein content was lower ($P < 0.05$) in the treatment groups compared to the control. Reduced protein in the treatment cheeses could be a result of higher salt content in these treatments, which enhances whey drainage.

Results in Table (8) illustrated that ash content increased with the increased levels of Gum Arabic and fat. These results are in line with those reported by Dhuol (2015) who used different levels of cassava powder to manufacture the Sudanese white soft cheese and reported that total ash increased with the levels of cassava powder. These results were in accordance those reported by Karaman *et al.* (2013) who stated that, as ripening proceeded, total ash content in all the cheeses increased, possibly due in part to syneresis. This data demonstrates the highest ash level was among the treatment cheese. This upward ($P < 0.05$) trend in ash content may be due to greater salt retention in these cheeses.

Results in Table (8) indicated that total solids increased with the levels of Gum Arabic and fat. These results were in line with those reported by Abdel Razig and Babiker (2009) who obtained that the kind of acidulate seems to have a significant effect ($P \leq 0.05$) on total solids of the resultant cheese, the white soft cheese made by the lemon juice gave the highest total solids (53.32%) followed by orange juice (51.70%) and lowest total solids were recorded by grapefruit juice (49.48%). The total solids content of the cheese gradually increased throughout the storage period. These results were also in line with those reported by Hamid (2014) who stated that the total solids content of the cheese samples with 0.1% cumin oil was significantly ($P < 0.001$) higher ($52.75 \pm 5.16\%$) than that of the control cheese samples ($48.21 \pm 8.43\%$).

The pH content of cheese samples decreased with levels of Gum Arabic and fat (Table 8). These results were not in accordance with those reported by Alnemr *et al.*, (2015) who reported that the pH of all treatments values were higher than control in the beginning and end of storage.

Results in Table (8) illustrated that volatile fatty acid of the cheese samples increased with the levels of Gum Arabic and fat in majority of treatments. These results were in line of those reported by Dhuol (2015) who stated that there were significant differences ($P < 0.05$) in the total volatile fatty acids between all the treatments.

In Table (9) fat content in the cheese samples increased significantly ($P < 0.05$), these results were in coincidence with those reported by Hamid *et al.* (2012) who stated that there were no significant differences ($P < 0.05$) in the fat content between all treatments.

Results in Table (9) illustrated that total bacteria decreased with levels of Gum Arabic and fat in major treatments. These results were in line with those of Dhuol and Hamid (2014) who reported that total bacteria count increased with the levels of cassava powder, when they used different levels of cassava powder in the manufacturing of the Sudanese white soft cheese. The results also are in line with those of Alsawaf and Alnaemi (2011) that showed that the effect of *Nigella sativa* seeds on some poisoning and pathogenic bacteria of a white cheese made from ewe's milk and they reported that total bacterial count decreased with the levels of *Nigella* seeds and the storage period.

Results in Table (9) showed that coliforms count decreased with the levels of Gum Arabic and fat. These results were in line with those reported by Abdalla *et al.* (2012) who studied the coliforms count of the cheese samples stored in five different containers. They found that the coliforms decreased from the day zero up to the day 180 of the storage period and not detected in some containers from the day 120 of the storage period.

Results in Table (9) indicated that lactic acid bacteria increased with the levels of Gum Arabic (0.75% and 3%) of fat and increased with the levels of gum 0.5% and 2% of fat and decreased in the remaining treatments with levels of Gum Arabic and fat. These results were in accordance with those reported by Picon *et al.* (2016) who stated that the levels of mesophilic lactic acid bacteria slightly exceeded log cfu/g-1 at day one, kept fairly constant during the first 30 day and decreased by 0.5 log units at day 60. No significant differences were recorded for mesophilic lactic acid bacteria between production areas or seasons at day one and differences during

ripening were small. Presumptive lactobacilli counts increased sharply from day one to day 15 and maintained their levels until day 60.

Results in Table (9) illustrated that yeasts and mould decreased with the levels of Gum Arabic and fat. These results were in line of those observed by Abdalla *et al.* (2012) and Dhuol (2015) who stated that yeasts and moulds decreased with the levels of cassava powder in most samples, However, Abdalla *et al.* (2012) studied the yeast and moulds counts of Sudanese white soft cheese store in five different containers, they found that the yeasts and moulds increase from the day zero up to day 75 of the storage period. The constant increase of yeasts and moulds during storage might be due to the fact that yeast and moulds counts could metabolize lactic acid and lower pH value (Turkoglu *et al.*, 2003). Moreover, Nour El Daim and El Zubeir (2007) found that the heat treatment and processing improve the cheese quality via reducing the counts of yeasts and moulds.

Results presented in Table (10) showed that colour, flavour, texture and saltiness of the cheese samples decreased with the levels of Gum Arabic and fat. The findings supported the work of Dhuol (2015). These findings were in accordance with those recorded by Fado (2010) who reported that storage period significantly affected the sensory evaluation of the white soft cheese made from different level of spearmint oil. Also Hamid (2014) found that the colour and texture did not affected by cumin oil concentration. However, the flavour and taste scores of the cheese samples with cumin oil concentration were significantly higher than those of the control cheese samples. These results were similar to those found by Elhaseen *et al.* (2013), while Miocinovic *et al.* (2014) demonstrated that the appearance as well as textural quality of both low-fat ultra-filtered cheeses

was considered very satisfactory at all sampling ages with no significant differences ($P < 0.05$) between the cheeses.

Results in Table (11) revealed that protein contents decreased with levels of fat. These results were in harmony with those reported by Suliman *et al.* (2013) who studied the effect of level of milk fat on the compositional quality of Sudanese white cheese during storage and he stated that the level of protein was affected significantly ($P \leq 0.05$) by fat content.

This result were in line with those of Rahimi *et al.* (2007) who stated that the protein content of all treatments decreased during ripening and that decreased in protein content could be due to the proteolysis and subsequent diffusion of free amino acids into the surrounding brine.

These results in Table (11) showed that ash content, total solids, volatile fatty acids and fat contents were increased with the level of fat, while the pH value decreased. These results were in line with those reported by Dhuol (2015) who used 0.5, 0.75 and 1% cassava powder to manufacture a Sudanese white soft cheese and they stated that all these characteristics increased with both the levels of cassava powder and storage period. These results were not in harmony with those of Hamid *et al.* (2012) who studies the effect of adding cardamom powder to goat's milk curd on the quality of white cheese during storage. They reported that total volatile fatty acids decreased with the levels of cardamom powder and increased with the storage time. Similar results were reported by Elhassein *et al.* (2014).

Results in Table (12) illustrated that coliforms, lactic acid bacteria and yeasts and moulds decreased with the level of fat, while total bacteria counts increased at levels of 2% fat. These findings were in accordance with those reported by Dhuol (2015) who stated that the increased of total

bacterial count during early storage period from day zero up to day 60 could be attributed to rapid growth of microorganisms. Similar results were supported by Abdalla *et al.* (2012) who studied the total bacterial counts of a Sudanese white soft cheese stored in five different containers. They also stated that total bacterial count increased from day zero up to day 75 of the storage period and then decreased.

Lactic acid bacteria decreased with the level of fat. The decreased of these bacteria could be attributed to the low storage temperature during ripening (Kasimoglu *et al.*, 2014). These results coincided with those of Miucinovic *et al.* (2014) who stated that at the beginning of the study period, the number of Bifidobacteria was significantly lower than the number of lactoacidophillus. Dhuol and Hamid (2014) stated that coliforms bacteria counts decreased with storage period and completely disappeared at the end of the storage. The disappearance of the coliforms could be due to the decreased of the pH values of the cheese samples. These results were in accordance with the work of Abdalla *et al.* (2012) who stated that the coliforms decreased from the day zero up to the day 180 of the storage period.

Yeasts and Moulds decreased with the level of fat, these result also were not in harmony with those reported by Abdalla *et al.* (2012) who stated that the yeasts and moulds increased from the day zero up to day 75 of the storage period.

Nour El-Daim and El Zubeir (2007) found that the heat treatment and processing improve the cheese quality via reducing the counts of yeasts and moulds. These results were not in line with those of Kheir *et al.* (2011) who found that the Streptococci of white cheese made from *Solanum dublum*

extract and rennet decreased from the day one up to the day 90 of the storage period, yeasts and moulds increased significantly with the storage.

Data in Table (13) illustrated that colour, flavour and saltiness of the cheese samples decreased with the level of fat, while textures were not affected by the fat level. These results were in agreement with those reported by Naser *et al.* (2016) who studied the sensory characteristics of white soft cheese made from sunflower (*Helianthus annuus*) seeds enzyme with different milk sources they stated that the cheese showed that milk source had significant ($P<0.05$) variation, whereas coagulant type revealed a significant difference ($P<0.05$) in the sensory characteristics of the manufactured cheese.

These results were in harmony with those of Gulzar *et al.* (2015) who reported that although butter flavour retention in cream cheese is greatly influenced by the fat. Also the results supported with those of Alnemr *et al.* (2015) who studied effect of synergized filler as protein base substitution and replacer on technological properties of low-fat spreadable processed cheese analogue. They stated that the synergized replacer used decreased the cohesiveness during storage period for treatment 1 and 2, while treatment 3 was similar with control which is increased during storage. Moreover, they added that gumminess and hardness values were decreased for all treatments including control. Sensory evaluation showed that 1, 2 had significantly higher flavour spreadability and colour scores. Similar results were obtained by Hamid (2014) who reported that sensory characteristics of the cheese samples as affected by storage period showed significant variations ($P<0.05$) in the colour flavour, taste and texture for all treatments. The best colour was reported for the cheese samples at day 7

and thereafter decreased in scores. The flavour, taste and texture of cheese samples showed the same trend.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. The present study aimed to utilize Gum Arabic as replacement ingredient for improving organoleptic properties of Sudanese white cheese.
2. Additional of Gum Arabic to Sudanese white cheese enhanced organoleptic properties with good compositional quality.
3. Gum Arabic significantly ($P < 0.05$) affected the total solids, fat, protein and volatile fatty acid of Sudanese white cheese, while there was no significant effect on ash and pH. Total solids and pH decreased with the addition of gum Arabic, while fat, protein, ash and volatile acid increased.
4. The storage period significantly ($P < 0.5$) affected the the physico-chemical characteristics of Sudanese white cheese. Total solids, fat, protein, and volatile fatty acid and pH of Sudanese white cheese significantly ($P < 0.05$) affected by storage period, while there were no significant effects on ash and pH.
5. The microbiological characteristics of cheese samples total bacterial counts, lactic acid bacteria and yeasts and moulds were significantly ($P < 0.05$) affected by the levels of Gum Arabic, while there was no significant effect on coliforms.
6. The better microbiological quality of Sudanese white cheese samples was recorded in the cheese made without gum Arabic (control) and maximum values for the lactic acid and yeast and moulds.

7. From the present research, the overall acceptability of Sudanese white cheese is more with respect to its appearance texture and sensory. Cheese samples made without Gum Arabic recorded the best scores for colour, texture and flavour.

Recommendations

From the present study following recommendations could be written:

1. The use of Gum Arabic in the manufacturing of dairy products such as yoghurt, ice cream and mish cheese, therefore it is recommended that it should be manufactured locally on the small scale as well as large scales.
2. When used high concentration of Gum Arabic levels in the manufacturing of Sudanese white cheese, it is better to pasteurization of milk with high temperature to avoid bitterness and to reduce the microbial load of the cheese.
3. Standardized by skim milk powder obtain to improve properties (viscosity) and sensory characteristics of Sudanese white cheese.
4. Further work is recommended on using fat replacers (Gum Arabic, guar, pectin ... etc.) to improve the texture of Sudanese white cheese.
5. Further investigation on Sudanese white cheese made from other milk (ewe's goat, camels, mixture of two milk or more).
6. Storage period duration not more than 60 days.

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APPENDIX 1

Sensory evaluation sheet for white soft cheese

Name.....

Date

Sample No.	Colour	Flavour	Texture	Saltiness	Remarks
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Colour	Flavour	Texture	Saltiness
1. Acceptable	7	1. Extremely intense	9
2. Slightly acceptable	5	2. Intense	7
3. Moderately accep	3	3. Moderately intense	5
4. Not acceptable	1	4. Slightly intense	3
		5. Poor	1
		1. Very soft	9
		2. Soft	7
		3. Slightly soft	5
		4. Not acceptable	3
		5. V. tough	1
		1. over salted	9
		2. Slightly acceptable	7
		3. Moderately accept.	5
		4. Slightly salted	3
		5. poor	1