ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY (AAiT)
CHEMICAL ENGINEERING DEPARTMENT
FOOD ENGINEERING STREAM

EVALUATION OF CHEDDAR AND COTTAGE CHEESE PRODUCTION FROM DOE AND EWE MILK

A Thesis submitted to the School of Graduate studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in Food Engineering

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List of Abbreviations

AAU	Addis Ababa University
AAiT	Addis Ababa institute of Technology
AOAC	Association of Official Analytical Chemists
APC	Aerobic Plate Count
Cfu	Colony forming units
CSA	Central Statistical Authority
EHNRI	Ethiopian Health and Nutrition Research Institute
FAO	Food and Agriculture Organization
Fig	Figure
GSRREC	Georgia Small Ruminant Research and Extension Center
HACCP	Hazard Analysis and Critical Control Points
Lab	Laboratory
MC	Moisture Content
Ml	Milliliter
Ppm	parts per million
RDA	Daily dietary allowances
SPSS	Statistical Package for Social Scientists
SSA	Sub-Saharan Africa
TQM	Total quantity of milk
UNICEF	United Nations International Children Education Foundation
UNRRA	United Nations Relief and Rehabilitation Administration

Abstract

The study was aimed to produce cheddar and cottage cheese from doe and ewe milk. The sources of milk were from Arsi Negele and Kofele areas of Oromiya region. Cheddar cheeses were made from whole doe, whole ewe milk and their mixtures contained ratio of 25, 50 and 75% of doe and ewe milk using standard procedure for cheddar cheese processing technology. The proximate, microbiological, Physico-chemical, sensory analysis and yield calculation of the cheeses were made at chemical Engineering laboratory, Holleta agricultural research center, Ethiopian health and nutrition research institute.The proximate analysis result showed that cheeses made from 100% doe milk had the lowest moisture content (27.77%) and highest fat content (54.80%) but a lower yield (0.66kg/5kg of whole milk) compared to cheeses made from 100% ewe milk (35.29%, 30.1%, 0.88kg/5kg of whole milk respectively). Other mix ratios had intermediate values between the two specious of cheese ($p<0.05$). No significant differences in the values of protein, total solid and lactose content of sampled cheeses were found. Microbiological results showed that all cheeses made were within the limit range for acceptable conditions for consumers ($< 1* 10^4$ cfu/g). Physico – chemical analysis result showed that whole ewe milk had highest viscosity of all cheeses (3.04mPas). Three main stage of cheddar cheese making was considered for pH measurement. These stages were ripening, cooking and cheddaring. The decrease in pH was most rapid in 100% doe milk and slowest in that of 100% ewe milk. Textural analyses result showed that cheese made from 100% doe milk was harder (0.65 N/g) and less brittle than those from their combination. The cheese from 100% ewe milk is the softest (0.30 N/g) compared to mix ratios and whole doe milk. Sensory analysis result showed that cheeses made from 50% ewe and 50% doe milk received, in general higher scores for body texture (8.94), flavor (8.81) and overall acceptability (8.98) than cheeses from whole and their combinations ($p<0.05$). The mean yield of cottage cheese was 0.33kg/ 2kg of whole milk and 0.45kg/ 2kg of whole milk for 100% doe milk and 100% ewe, respectively. From over all analysis the best acceptable and quality cheese was obtained from mix ratio of 50% ewe and 50% doe milk. The thesis generally includes processing technology and evaluation of cheddar cheese made from doe and/or ewe milk. As a result an economically feasible production system has been recommended by scaling up to industry level.

CHAPTER ONE

1. Introduction

1.1 Background

Sub-Saharan Africa has the most rapidly growing population of any region of the world. The demand for dairy products in sub-Saharan Africa continues to increase with the overall growth rate in the consumption of milk and milk products being estimated at about 2.1% per annum. The growth in demand results from rapidly rising populations, urbanization and some increase in per capital income. On the basis of population growth alone and a constant per capital consumption level of 27 kg the total requirement for dairy products would increase by 400 million kg each year. An increase in per capital incomes would add to this demand and it is projected that total demand will grow by at least 500 million kg, i.e. by around 3.5% per annum at current levels of production (CSA, 2008).

Ethiopia, a landlocked country in the Horn of Africa, is located at 8.0º N and 38.0º E (The World Fact Book 2002). The total land area of the country is 1.1 million km^2 and the total human population is estimated at 79,221,000 from which 84% is rural and 16% is urban (CSA, 2008). The country enjoys diverse topographic and climatic conditions. These consist of a high central plateau ranging from 1,800 to 3,000 meters above sea level, a rift valley that divides the country from north to south with altitudes ranging from 1,000 to 1,800 meters and lowland plain areas of less than 1,000 meters in altitude. Depending on the altitude; temperatures range from less than 10 ^{0}C in alpine areas to 35 ^{0}C and higher in lowland areas. Moreover, rainfall in most of the country is adequate for crop and pasture production (Mengistu, 1987). The favorable climate throughout the country supports use of improved, high-yielding animal breeds and offers a relatively disease-free environment for livestock development.

The Ethiopian economy is highly dependent on agriculture. The livestock sub sector plays a vital role as source of food, income, services and foreign exchange to the Ethiopian economy, and contributes to 12% (Ayele *et al*., 2003). Livestock species consist of camels, cattle, sheep, goats, horses, mules and donkeys. The total cattle population in Ethiopia is estimated to be about 49.3 million.

Out of this total cattle population, the female cattle constitute about 55.48 percent and the remaining 44.52 percent are male cattle. 25.02 million Sheep are estimated to be found in the country, out of which about 73.38 percent are Ewes, and about 26.62 percent are males. The number of goats in the country is estimated to be about 21.88 million. Out of these total goats, about 69.84 percent are Does and 30.16 percent are males. There are also about 1.79 million horses, 5.42 million donkeys, 335 thousand mules, and 760 thousand camels in the country (CSA, 2008).

Ethiopia is believed to have the largest livestock population in Africa. This livestock sector has been contributing considerable portion to the economy of the country, and still promising to rally round the economic development of the country. It is eminent that livestock products and by-products in the form of meat, milk, honey, eggs, cheese, and butter supply the needed animal protein that contribute to the improvement of the nutritional status of the people. Livestock as well confer a certain degree of security in times of crop failure. Furthermore, livestock provides farmyard manure that is commonly applied to improve soil fertility and also used as a source of energy (CSA, 2008).

In the first half of the 20th century, dairying in Ethiopia was mostly traditional. Modern dairying started in the early 1950s when Ethiopia received the first batch of dairy cattle from United Nations Relief and Rehabilitation Administration (UNRRA). With the introduction of these cattle in the country, commercial liquid milk production started on large farms in Addis Ababa and Asmera (Ketema, 2000).

Compared to other countries in Africa, Ethiopians consume less dairy products. Per capita consumption of milk in Ethiopia is as low as 17 kg per head while the average figure for Africa is 26 kg per head (Gebrewold *et al*., 1998).

Besides providing income-earning opportunities for the poor, dairy development, especially at the smallholder sector level, can improve the nutritional status of Ethiopian children by making available milk for consumption and increasing household income.

The dairy industry is not developed even as compared to east African countries like Kenya, Uganda and Tanzania. Regarding dairy production, the national milk production

remains among the lowest in the world, even by African standards (Zegeye 2003). The demand for dairy products is increasing as ever. Ethiopia is not self-sufficient in milk and a considerable amount of foreign exchange has to be spent on the import of dairy products. Dairy production as a biologically efficient system that converts large quantities of roughage, the most abundant feed in the tropics, to milk, the most nutritious food (De Leeuw *et al*., 1996).

The contribution of the different livestock species to the total production of milk is about 81.2% from cattle, 6.3% from camels, 7.9% from does and 4.6% from ewes (CSA, 2008). Due to the highly perishable nature of milk and mishandling, the amount produced is subjected to high post-harvest losses. Losses of up to 20–35% have been reported in Ethiopia for milk and dairy products from milking to consumption (Getachew, 2003).

Small ruminants are an integral part of mixed-farming systems throughout Small ruminants hold several roles in Ethiopia. They provide meat, milk and skins. Small ruminants are kept for various purposes. Their role for income generation, food supply like meat and milk, and financial security for the rural poor population is documented (Gryseels, 1988; Zelalem and Fletcher, 1993; Barrs, 1998; Workneh, 1999).

Goats (Capra hircus) are found across all agro-ecological environments in nearly all livestock production systems (Winrock International, 1983) and are suitable for very extensive to highly mechanized production systems (Wilson, 1982; FAO, 1987). There are approximately 570 breeds and types of goats in the world, of which 89 are found in Africa. Ethiopia endowed with different agro- ecological zones of highlands, sub-humid, semi-arid and arid environments (Farm Africa, 1996). These goats are grouped into 9 distinct genetic entities. The goat and sheep research program, which includes management studies associated with breed evaluation and improvement programs, was started at Holetta and Melka Werer research centers in Ethiopia (EARO, 2000).

Sheep (*Ovis aries*) are believed to have been among the first animals to be domesticated, preceded by the dog and goat. The domestication of both sheep and goats probably dates back to the pre-settled agricultural period. It is assumed that the majority of today's domestic sheep breeds descended from the *urial* which is currently found in central Asian countries and in northern Iran extending up to Tibet and northern China (EARO, 2000).

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Milk and milk products form part of the diet for many Ethiopians. They consume dairy products either as fresh milk or in fermented or soured form. Fellke and Geda (2001) estimated that 68 % of the total milk produced is used for human consumption in the form of fresh milk, butter, cheese and yogurt while the rest is given to calves and wasted in the process.

Cheese is an ancient, traditional food and is an important dairy product; Humans have been making and eating cheese since prehistoric times. Purpose for preparation is to gather the interest of the people, because it is nutritious food, excellent source of fat, has high calorific value, good source of protein and rich source of vitamin A, D, Ca and P.

Given the high potential for dairy development and the ongoing policy reforms and technological interventions, success similar to that realized in the neighboring Kenya under a very similar production environment is expected in Ethiopia. In this experimental thesis cheddar type cheese was prepared from Doe and Ewe milk for substitution of import and cottage cheese was also prepared from Doe and Ewe milk for local consumption and also appropriate parameters was identified for best quality.

1.2 Statement of the Problem

Ethiopia holds the largest livestock population in Africa, estimated at about 43.1 million heads of cattle, 23.6 million sheep and 18.6 million goats (CSA, 2008), the total national milk production and processing remains among the lowest in the world, even by African standard. There is a wide gap between the potential demand of the growing population of Ethiopia and supply of milk and milk products.

Doe and Ewe milk has higher digestible protein and fat content than cow milk. This combination is beneficial in infant diets as well as in invalid and convalescent diets. They tend to have a buffering quality that makes it useful in the treatment of ulcer patients. Doe milk is useful in the treatment of dyspepsia, peptic ulcer, pyloric stenosis, liver dysfunction, jaundice and biliary disorder. Based on these facts the effort to popularize and encourage the consumption and processing of Doe and Ewe milk cheese among the populace should be intensified since Doe and Ewe are owned by nearly all the household unit unlike cow which is more expensive, require more feed and large areas to graze, and also they are not suitable for small scale farmers.

Ethiopia is not self-sufficient in milk products like cheese so considerable amount of foreign exchange has to be spent on the import of dairy products. Despite the huge potential that the country posses for increased milk production and processing that can even be stretched to quantities beyond its domestic needs, there is a chronic shortage of the product in most part of the country arising mainly from insufficient production coupled with inhibitive cultural taboos related to consumption and absence of processing facilities.

Cheese from Doe and/or Ewe milk is not currently produced in Ethiopia, but cheeses from Doe and/or Ewe milk are imported from abroad and available in Ethiopia super markets. Therefore, processing of milk from doe and ewe can be used as spring board in resource utilization as well as import substitution. Cheese processing can contribute in food self sufficiency specifically in agro-pastoral and pastoral areas of Ethiopia where small ruminants are available and indigenous practices are undergoing.

1.3 Objective

1.3.1 Primary Objectives

The general objective of the study was to produce cheddar and cottage cheese (Ayib) from Doe and Ewe milk in order to maximize resource utilization in pastoral and agro-pastoral areas of Ethiopia.

1.3.2 Specific Objectives

The specific objectives of the study were:

- Evaluate the composition of the indigenous Doe and Ewe milk.
- Assess the Physico- chemical and microbiological quality of milk and Cheese.
- Evaluate hedonic tests for Cheddar cheese from doe and ewe milk.
- Study the processing technology for Cheddar and Cottage Cheese.
- Conduct techno-economic feasibility study.

1.4 Significance of the Study

Cheese is an excellent source of protein, fat, vitamins and minerals such as calcium, phosphorous, iron, zinc, vitamin A, riboflavin and Vitamin B_{12}, making it an important food in the diet of both young and old. It has great taste with its nutritional value. Cheddar cheese contains little lactose for lactose mal-digesters. Cheddar cheese also has higher buffering capacity than other dairy products. From various types of cheese cheddar cheeses have a longer shelf life and salty test results preference and popularity compared to others types. In this experimental thesis the production of cheddar cheese from Doe and Ewe milk in Ethiopia was done.

Milk and dairy products from Doe and Ewe are very important for proper human nutrition, where cow milk is not readily available or affordable. Nutrient supply from Doe and Ewe milk is very valuable in combating under and malnutrition of people in poor areas and countries and also for people who has cow milk allergies.

The study aims to demonstrate the method and technique for Cheddar cheese production and determine its quality in terms of consumer interest which is potential avenue of increasing milk storage life and minimizing post harvest losses with such processing technology introduce the opportunity of cheese making from Doe and Ewe milk in Ethiopia due to strong demand for processed products both in domestic consumption and export. It would also be nutritionally advantageous that a stable and nutritious food which can be stored for periods of time will be introduced. Additionally, cheese making practice from doe and ewe milk can attract investors and entrepreneur’s interms of income generation and creating employment opportunity in the milk production areas.

1.5 Structure of the Experiment

Fig 1.1 Structure of the Experiment

CHAPTER TWO

2. Literature Review

2.1 Overview of Dairy Processing Industries

Milk is converted into a wide variety of milk products using a range of advanced processing technologies called dairy processing. The dairy industry is probably the most diverse and flexible sector of the food industry. The flexibility of milk as a raw material resides in the chemical and physico-chemical properties of its constituents, many of which are unique. Dairy processing includes the products such as variety of cheeses, yoghurt, butters, spreads, ice cream, dairy desserts, fat reduced content and health-promoting components. Today, most milk is processed in large, highly mechanized and automated dairy factories (Chandan, 2008).

Milk is the secretion of the mammary gland of female mammals (over 4000 species), and it is often the sole source of food for the very young mammal. The role of milk is to nourish and provide immunological protection. The milks produced by cows, buffaloes, sheep, goats, and camels are used in various parts of the world for human consumption. For much of the world population, cow milk accounts for the large majority of the milk processed for human consumption (Young, 2006). This chapter provides an overview of dairy processing from cow and small ruminant animals, and also emphasizes cheese making process from Doe and Ewe milk.

2.2 Dairy Production System in Ethiopia

In the first half of the 20th century, dairying in Ethiopia was mostly traditional. Modern dairying started in the early 1950s when Ethiopia received the first batch of dairy cattle from United Nations Relief and Rehabilitation Administration (UNRRA) (Ahmed *et al*, 2003). With the introduction of these cattle in the country, commercial liquid milk production started on large farms in Addis Ababa and Asmara (Ketema, 2000). Government intervened through the introduction of high-yielding dairy cattle in the highlands in and around major urban areas.

The government also established modern milk processing and marketing facilities to complement these input-oriented production efforts.

In 1960, UNICEF established a public sector pilot processing plant at Shola on the outskirt of Addis Ababa in order to enhance growth of the dairy sector. The plant started by processing milk produced by large farms. The plant significantly expanded in a short period and started collecting milk from smallholder producers in addition to large farms. This led to further expansion of large dairy farms. During the second half of the 1960s, dairy production in the Addis Ababa area began to develop rapidly as a result of the expansion in large private dairy farms and the participation of smallholder producers with indigenous cattle facilitated by establishment of milk collection centers. Subsequently, different dairy development projects were launched in different parts of the country. The distribution of exotic dairy cattle, particularly the Holstein Friesian, in different parts of the country, especially around the major urban areas, also contributed to the further development of dairying in Ethiopia (Ahmed *et al*. 2003).

Most of the researchers used different approaches at different time for the classification of milk production system in Ethiopia (Beyene, 2004). Based on climate, land-holding size and farming systems, four main dairy production systems are recognized in Ethiopia (Zegeye, 2003), namely: Pastoralism, Highland smallholder, Periurban and Urban. Moreover, it is concluded that the production of milk in East African countries in general and in Ethiopia in particular is dominated by smallholder dairy production system.

2.2.1 Pastoralism

Pastoralism is a system mainly operating in the rangelands where the peoples involved follow animal-based life styles, which requires of them to move from place to place seasonally based on feed and water availability. For food, pastoralists mainly depend on milk, and their accumulated wealth and savings are in the form of live animals. Milk production under the systems is strictly seasonal and range condition-dependent being surplus in the wet season and restricted in the dry season (Zegeye, 2003).

The lowland accounts for 27% of the milk produced (Getachew and Gashaw, 2001). Because of the erratic rainfall pattern and related reasons, resulting in shortage of feed, milk production per unit is low and highly seasonal. More milk will be produced in the wet season where pastoralists would mostly conserve and convert the surplus milk into cheese, butter, and trade off to the highlanders in the peripheral markets for grain. In the pastoral areas, milk production is the major activity as food and income source, where the livelihood of the semi-nomadic transhumance population is dependent on livestock. Cattle dominate as source of milk for the population (55.4%) followed by camel (15.3%), Does (13.7%) and Ewes (6.4%) (Coppock, 1994).

2.2.2 Highland Smallholder Production System

Highland smallholder production system operates in most highlands of Ethiopia, with increasing population, there is an ever- decreasing share of pastureland for grazing; and with the corresponding increase in the cultivated area, there is a need to continuously produce more animal draught power. As a result, the rural farmers in these areas incorporate small-scale dairy production with crop farming with the objective of producing animal power for tilling the land (Zegeye, 2003).

The above two production systems are the most predominant milk production system accounting for over 97% of total national milk production. These systems are based on low producing indigenous breeds. Livestock are kept under traditional management conditions and generally obtain most of their feed from native vegetation, aftermath grazing and crop residues. The systems are not market-oriented and most of the milk produced in it is retained for home consumption. The level of milk surplus is determined by the demand for milk of the household and its neighbors, the potential to produce milk in terms of herd size, production season and access to a nearby market. The surplus is mainly processed using traditional technologies and milk products such as butter, ghee, ayib and sour milk are usually marketed through the informal market after the households satisfy their needs (Tsehay, 2002).

2.2.3 Urban Milk Production System

By the virtue of their location, producers are not expected to have access to agricultural or pasture land, as the operation takes place within cities and as a result, they are forced to buy their feed. Based on the scale and level of operations, this production system could be subdivided into small scale and large scale. Urban milk production system inside and around Addis Ababa consists of small, medium and large dairy farms producing about 35 million liters of milk annually (Tsehay, 2002). Out of the total volume of milk produced in and around Addis Ababa, 73% were marketed, 10% goes to calves and 9.4%, processed in to butter and 7.6% in to Ayib (Ethiopian cottage cheese) (Azage and Alemu, 1998). Although some farmers produce good quality milk, hygienic quality and composition of most milk marketed in such production systems is poor (Tsehay, 2002). Moreover, price is high even when quality of milk is low. No standards and quality control mechanisms or dairy policy exist to safeguard consumers.

2.2.4. Peri-Urban Milk Production System

Peri-urban dairy production system is mainly operational in areas where the population density is high, agricultural land is shrinking due to expanding urbanization, and labor cost is on the increase (Zegeye, 2003). Peri-urban dairy system occurs around cities, where demand for milk is high. Peri-urban milk production system includes smallholders and commercial dairy farmers working in the proximity of the city of Addis Ababa and other regional towns. Most of the improved dairy stock in Ethiopia is used for this type of production system. However, contribution to the total domestic milk supply for Addis Ababa remained at only 14% (Belachew *et al*, 1994).

The producers may or may not have access to cultivable or pastureland and some of them are usually left their few animals for grazing on the roadside. Animals they keep ranged from 50% crosses to high-grade breeds. On the other hand, the main sources of feed are agro-industrial by products (e.g. brewery waste and oilseed cakes), cultivated fodder crops and crop residues (Nell, 1992).

Urban and peri-urban dairy production system is an important component of livestock production system in Ethiopia (Yoseph *et al*, 2003).

Urban and per-urban milk production has developed in and around major cities and towns, which have high demand for milk. The system comprised small and medium sized dairy farms using crossbred and high grade dairy breeds. Herd sizes are small due to urbanization, land size limitations and economic capacity. Increasing demand for more and diversified dairy products, particularly in urban centers, will be a major driving force and a challenge for the development of peri-urban dairy production systems. The substantial demand-supply variation in milk and milk products for the major urban centers in Ethiopia shows the untapped potential for the development and flourishing of peri-urban dairy farms. Large commercial and smallholder peri-urban dairy production systems have tremendous potential for development and could play a significant role in minimizing the acute shortage of dairy products in urban centers (Azage and Alemu, 1998).

From major species used for milk production in Ethiopia cattle produce 83% of the total milk. Although milk production is increasing by 1.2% per annum, the demand-supply variance for fresh milk is ever widening and the per capita consumption diminishing. The total milk available in percentage by the year 1985, 1998, 2005 are 1125, 1170, 2623 million liters respectively and commercial imports grew rapidly at 24.2% per year (Tambi *et. al.* 2001).

The key development issues in dairy are low milk production complicated by widespread food insecurity, growing gap between supply and demand in urban areas, and low average milk productivity. The goals of the development plan include increasing milk production from indigenous cows by 100% and that of the crossbred by 25%, increasing milk processing industries by similar orders of magnitude, increasing milk processing plants by three-fold, improving quality of the milk produced by 50%, increasing per capita milk consumption by 6 litres and increasing farmer's income from dairy by 50% (Felleke and Geda, 2001).

2.3 Milk Collection, Handling, Transportation and Processing in Ethiopia

Milk and milk products form part of the diet for many Ethiopians. They consume dairy products either as fresh milk or in fermented or soured form. 68% of the total milk produced is used for human consumption in the form of fresh milk, butter, cheese and yogurt while the rest is given to calves and wasted in the process.

Butter produced from whole milk is estimated to have 65% fat and is the most widely consumed milk product in Ethiopia. Of the total milk produced, around 40% is allocated for butter while only 9% is for cheese (Fellke and Geda, 2001).

The consumption of milk and milk products vary geographically between the highlands and the low lands and level of urbanization. In the lowlands, all segments of the population consume dairy products while in the highlands major consumers include primarily children and some vulnerable groups of women. The limited statistical data available on potential milk demand suggest that demand for milk will increase, at least in the urban centers and among the people with high purchasing power (Zegeye, 2003).

No one can deny the fact that cows are the primary dairy animal species in many countries and in Ethiopia to provide humans with nutritious food through the abundance of their lacteal secretion. Doe, Ewe and other minor dairy species will never be able to compete with cows in terms of volume of milk production. However, the contribution of milk from other domesticated dairy species to the survival and well being of people is immense and invaluable, especially in areas where cows have difficult to survive.

Nevertheless dairy-cow-dominated dairy industry and more diversified in domestic productions, and it is already in the market place on shelves of many food stores, where variety of domestic and imported dairy products from Does and Ewes are now available with high quality. Consumers of such new products found in grocery stores and on restaurant menus are increasingly interested in the histories, origins, and comparative values of these diverse products from species other than dairy cows (Young, 2006).

2.4 Over View of Milk Production from Small Ruminants

Milk is obtained by milking Doe and Ewe. Milk is formed in the udder and flows from the udder tissue into the teats. The milk flow to the teats is stimulated by the presence of the kid(s) especially when the kids touch and press the udder when sucking.

Doe milk has been used successfully in cases of cow milk allergies and by patients with various metabolic and gastrointestinal ailments. Doe milk proteins can differ genetically from some cow milk proteins, and doe milk fat has usually a better profile of fatty acids. Doe milk cheeses have acquired a worldwide gourmet reputation, and demand is growing (Young, 2006).

Ewe milk has unique composition and is ideally suited for yogurt and cheese production. Ewe cheese production is well organized and promoted in some countries and in exports, where ewe cheeses are highly regarded, especially because of some official protection of origin label.

Genetic selection of dairy Doe and Ewe have succeeded in much higher milk yields, longer lactation length, and better udder conformation, especially among the Swiss breeds. Milk yield production data vary much from country to country for the same breed, depending on feeding, climate, and disease adaptation. Milk composition also varies between breeds.

Table 2.1 Doe and Ewe milk production (FAO, 2003)

Region/ Country	Milk production (Thousands of tones)	
	Ewe	Doe
Africa	1641	2745
Asia	3586	6291
Europe	2812	2421.4
America	456	359
Oceania	36	30
World	8075	11816

Source: FAO, 2003

2.4.1 Dairy Products Processed from Small Ruminants

A variety of products may be manufactured from Doe and Ewe milk, including fluid products (low fat, fortified, or flavored), fermented products such as cheese, buttermilk or yogurt, frozen products such as ice cream or frozen yogurt, or butter, condensed, and dried products (Loewenstein,1980). However, cheese is traditionally the main Doe and Ewe milk product produced and consumed in large quantities around the world. Significant amounts of fluid, evaporated and powdered Doe and Ewe milk products have been marketed in the United States and New Zealand for the past several decades.

Milk from Ewe is widely used for high quality cheese production in Spain, as elsewhere. In the last decades, the socio-economic context of the Mediterranean basin, where milk from Ewe is widely destined to cheese production, incited the profession to get involved in a global research-development work aiming to construct an effective economic system, for both milk producers and cheese makers.

2.4.2 Goat and Sheep Breeds and Their Distribution in Ethiopia

African goats could be grouped into three main families: the Dwarf goats of West and Central Africa, the Savannah goats of sub-Saharan Africa and the Nubian type goats of North Africa. The parents of the Nubian goats came from Asia. It is assumed that the first wave of goats entered Ethiopia from the north between 2000 and 3000 B.C. The ancestors of Ethiopian goats are closely associated with goat types which migrated from the Middle East and North Africa (Tesfaye, 2004).

According to earlier characterization work, indigenous Ethiopian goats have been phenotypic ally classified into 11 types while a recent genetic characterization showed only eight distinctively different types Figure 2.5 shows the distribution of goat types in Ethiopia. Some of the most important goat breeds are also presented in the figure (Farm Africa, 2004).

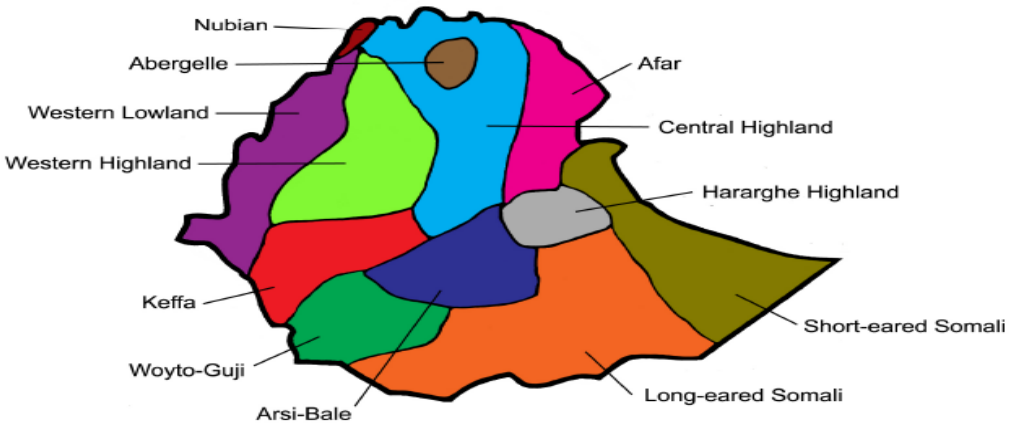


Figure 2.1. Geographic distribution of Ethiopian goats.

- **Abergelle:** goats are milked for domestic consumption. Their skin is also used to make aprons, containers, etc.
- **Afar:** goats are milked for domestic use or sale. The goats are maintained for meat, milk and skin production and for social affairs as they are commonly given away as dowry.
- **Arsi-Bale:** goats are reared for meat, milk and skin production. Manure is also a valuable product used to fertilize backyard farms.
- **Begayit:** goats have relatively large udders and are milked.
- **Central Highland:** goats skin is an exportable commodity while manure is used to fertilize backyard farms.
- **Hararghe:** Highland goats are kept for meat, milk, skin production and for social functions.
- **Keffa:** goat is related to the Western Highland goat. Goat meat is frequently eaten in areas where these goats are kept. They are also used for some social functions.
- **Somali:** Goats are divided in to the Short- and Long-eared Somali goats. Both the Short- and Long-eared Somali goats are milked extensively. Goat meat is also favored in these areas compared to mutton. Both types are reared for meat, milk, various social affairs and skin production.
- **Western Highland:** goats are known to be related to the Central Highland and Keffa goats. Goat milk is not consumed in these areas.

- **Western Lowland:** goats are also called Gumuz. Goats are milked in the pastoral and agro pastoral areas.
- **Woyto-Guji:** goats are known to be related to the Arsi-Bale types. Goats in these areas are kept for milk, meat, skins and manure production. They are also important for some social functions.

There are many types of dairy doe breeds in the world only some of the important breeds that have been introduced to Ethiopia earlier. Most of the breeds introduced to date have been dairy does with the main purpose of crossing with local does to improve milk production in areas where doe milk is known to be consumed. Some of the breeds are the following:

- Anglo-Nubian
- Beetal
- Boer
- Damascus or Shami
- Jamnapari
- Saanen and Toggenburg

Attempts have been made since 1975 to identify and characterize Ethiopian sheep breeds or types. Unsuccessful attempts have been made to establish elite flocks of identified sheep such as Afar, Blackhead Ogaden (Blackhead Somali), Horro and Menz in research centers and government farms. Other additional breeds/types such as the Washera sheep in the Amhara Region and Arsi-Bale sheep in the Oromia Region have been described to a limited extent. The map in Figure 2.11 shows distribution of some Ethiopian sheep breeds and a sketch of the Red Sea area showing the Bab El Mandeb route of fat-tailed sheep introduction into Africa.

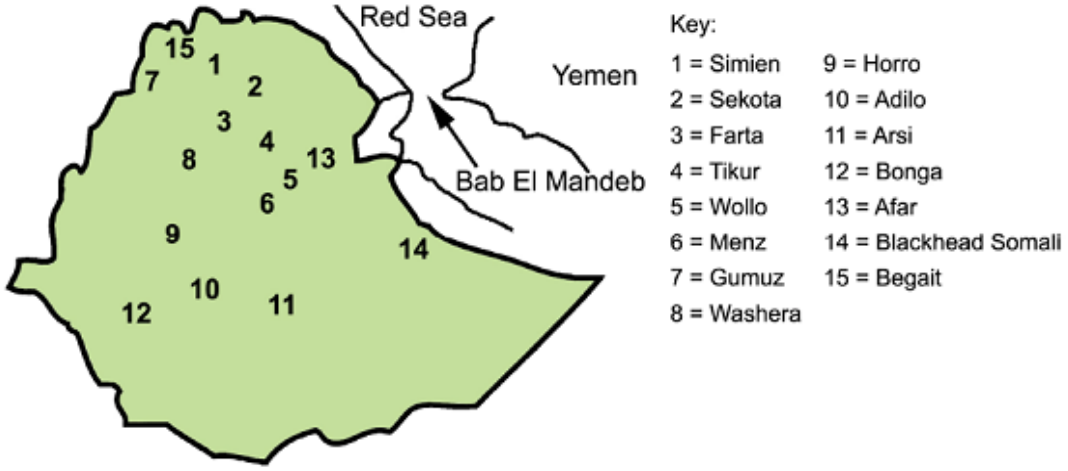


Fig 2.2 Geographic distribution of some of the major Ethiopian sheep breeds

Some of sheep breeds are listed as follows:

- Afar sheep
- Arsi-Bale sheep
- Horro sheep
- Menz sheep
- Washera (Dangla) sheep
- Important Exotic Sheep Breeds
- Awassi sheep
- Corriedale sheep
- Dorper sheep
- Hampshire sheep

Sheep have been milked for millennia, but mainly as part of triple-purpose breeding for fiber and meat production besides milk. Therefore official statistical records of dairy sheep populations, and sheep milk production and processing, are hard to find. In Ethiopia, there exists a great variation in climate and topography, harboring diversified livestock species which also have variability among themselves. The sheep found in Ethiopia could fall into different breeds and types whose habitat ranges from tropical to temperate environments. The present fat-tailed sheep of Ethiopia that are believed to have replaced the original African long-thin-tailed sheep came from Asia through the Strait of Bab El Mandeb. Although sheep were domesticated as dual purpose animals to produce wool and meat, early people would have valued sheep milk as well.

2.4.3 Doe and Ewe Milk Production and Processing

Milk yield of most Ethiopian indigenous breeds of does and ewes in their natural habitat is about half a litre per day (MOA, 1999). These animals thrive in a harsh environment where food and water are scarce during most periods of the year. Besides the high environmental temperature in their natural habitat, lactation puts an additional strain on the water balance of the animal. As a result, the lactating does and Ewes are confronted with two challenging physiological processes the need for conservation of water for themselves and milk production to promote kid growth and survival. Some breeds of Does and Ewes have a better capacity and maintain their milk yield during the first few days of water deprivation.

Doe and Ewe milk has played a very important role in the economic viability of many developing countries of the world, as swell as in the Mediterranean, Middle East, and eastern European countries, through its utilization for manufacture of cheeses and other products (Kosikowski, 1986). In addition to the economic, nutritional, and medical significance of Doe and Ewe milk in many developing countries, Doe and Ewe milk products also have recently gained increasing popularity among certain ethnic groups, health food lovers, gourmet lovers, Doe and Ewe farmers, and cheese enthusiasts in the United States (Park, 1990).

A large-scale expansion and industrialization of the dairy Doe and Ewe sector in many countries is difficult due to the low level of milk production, coupled with inadequate technological means and the small range of products made from the milk (Irvine, 1974).
In general, milk is a very nutritious drink. This is especially true for Doe and Ewe milk as is easier to digest for humans than cow milk. Milk is a healthy contribution to daily feeding; it supplies protein to the diet. Especially for children who still grow it is important to eat sufficient protein.

Fresh and normal doe milk from healthy and properly fed and milked animals is a white, opaque liquid with a slightly sweet taste that has practically no odor (Juàrez and Ramos, 1986). Production of quality doe milk should start at every farm level because flavor and

quality of the milk cannot be improved later in the processing stage. The basic principle is that the better the milk, the better the processed products.

It was about, for the milk producer, to obtain sufficient income in a region completely vowed to agriculture and for the cheese maker, to be able to transform milk of good quality, in sufficient quantity, to satisfy the ever increasing clientele of ovine cheese amateurs.

Milk drawn from the lacteal glands is highly perishable and easily affected negatively by improper handling from many factors such as feeding, handling of animals prior to and during milking, handling of the milk during and after milking, cooling and transportation, pasteurization, processing, packaging, and processing utensils (Deeth and Tamime, 1981). Quality of milk largely depends on the farm producer as well as workers at dairy processing plants. Milk is an excellent culture medium for bacteria and is used by nature easily, and thus is rapidly liable to deterioration. A clean milking environment is just as important as the milk composition. Good quality milk must contain no pathogens or organisms likely to damage the cheese, nor such foreign substances as antibiotics, antiseptics, or pesticide residues (Deeth and Tamime, 1981).

2.4.4 Physico- chemical and Nutritional Adequacy of Doe and Ewe Milk and Milk Products

Although Doe and Ewe produce approximately 2% of the world's total annual milk supply (FAO, 2003), their contribution to the nutritional and economic well being of mankind is tremendous in many parts of the world, notably in the Mediterranean countries and in the Middle East. Worldwide, more people drink the milk of Doe and Ewe than milk of any other single species. Doe and Ewe milk differs from cow or human milk in higher digestibility, distinct alkalinity, higher buffering capacity, and certain therapeutic values in human medicine and nutrition. Due to the unavailability of cow milk, Doe and Ewe milk and its products are important daily food sources of protein, phosphate, and calcium in developing countries (Haenlein, 1984).

Interest in dairy Doe and Ewe milk and milk products is a part of the recent trend in health food demand and consumption in some developed countries; there is also a renewed interest in Doe and Ewe milk as a substitute for those who suffer from allergies or intolerance against cow milk. Doe and Ewe milk cheeses also recently gained increasing popularity among certain ethnic groups, health food lovers, and private Doe and Ewe farmers in the United States (Park, 1992).

The major nutrient composition of Doe and Ewe milk resembles cow milk, whereas Doe and Ewe milk has its unique chemical, biochemical, physical, and nutritional characteristics compared to other species milk. Doe milk exceeds cow milk in monounsaturated fatty acids, polyunsaturated fatty acids and medium chain triglycerides, which are beneficial for human health, especially for cardiovascular conditions (Haenlein, 1992). The chemical composition and nutritional value of various types of milk is illustrated in table 2.5

Table 2.2 Chemical Composition and Nutritional value of various types of milk

Item	Doe	Cow	Ewe	Human
		Percent by mass		
Moisture	87	88	80.7	87.5
Protein	3.6	3.3	6.0	1.0
Fat	4.1	3.3	7.0	4.4
Carbohydrates	4.5	4.7	5.4	6.9
Isoleucine	1.207	0.199	0.338	0.056
Leucine	0.314	0.322	0.587	0.095
Lysine	0.290	0.261	0.513	0.068
Methionine	0.08	0.083	0.155	0.021
Threonine	0.163	0.149	0.268	0.046
Tryptophan	0.044	0.046	0.084	0.017
Valine	0.240	0.220	0.448	0.063
Argentine	0.119	0.119	0.198	0.043
Histidine	0.089	0.089	0.167	0.023
C_{10}	0.26	0.08	0.4	0.06

C_{12}	0.12	0.09	0.24	0.26
C_{11}	0.32	0.34	0.66	0.32
C_{16}	0.91	0.88	1.62	0.92
$C_{16.1}$	0.08	0.08	0.13	0.13
$C_{18.0}$	0.44	0.40	0.9	0.29
$C_{18.1}$	0.98	0.84	1.56	1.48
$C_{18.2}$	0.11	0.08	0.18	0.37
Mg per 100 grams (PPb)				
Cholesterol	11	14	11	14
Calcium	134	119	193	32
Magnesium	14	13	18	3
Phosphorus	111	93	158	14
Potassium	204	152	136	51
Sodium	50	49	44	17
Thiamin	0.05	0.04	0.07	0.01
Riboflavin	0.14	0.16	0.36	0.04
Vit B_6	0.046	0.042	0.09	0.011
Vit E	0.04	0.09	0.12	0.34
Microgram per 100 gram				
Vit A	56	31	42	64

Source: Haenlein, 1992

Many products can be manufactured from Doe and Ewe milk, including fluid, cultured, frozen, and dehydrated products. Standardization of milk composition, especially fat content, is essential to assure the legality of the finished product as well as its uniformity. Doe and Ewe milk and milk products have significant nutritional values in human nutrition as an alternative food for children and sick people, and also have higher nutrient bioavailability.

2.4.5 Comparison and Advantage of Doe and Ewe Milk Processing Over Cow Milk in Ethiopia

The milks produced by cows, buffaloes, sheep, goats, and camels are used in various parts of the world for human consumption. For much of the world's population, cow milk accounts for the large majority of the milk processed for human consumption.

Dairy production in sub-Saharan Africa can be categorized into traditional and improved production systems. Based on climate, land-holding size and farming systems, four main dairy production systems are recognized in Ethiopia, namely: Pastoralism, Highland smallholder, Periurban and Urban.

Goat and Sheep is the most versatile domestic animals in adaptation to arid and humid, tropical and cold, and desert and mountain conditions, providing people with many important products: meat, milk including yogurt and cheese. The world goat and sheep population was estimated to have increased between 1993 and 2003. Doe rank third and Ewe rank fourth, in terms of global milk production from different species after cattle and buffaloes. Doe and Ewe milk in Ethiopia are used for milking purpose extensively in areas like Somali, Afar and Oromiya regions. There are four high milk yielding breeds of does in the world. These are Alpine, Saanen, Toggenburg and Nubian. African goats can be grouped into three main families: the Dwarf goats of West and Central Africa, the Savannah goats of sub-Saharan Africa and the Nubian type goats of North Africa. The important dairy breeds have been introduced to Ethiopia with the main purpose of crossing with local doe and ewe to improve milk production in areas where doe and ewe milk is known to be consumed. As an example for does; a cross of Saanen with Afar and Highland doe types and Toggenburg with Somali does is discussed.

Doe and Ewe milk and milk products have significant nutritional values in human nutrition as an alternative food for children and sick people, and also have higher nutrient bioavailability. Great varieties of dairy products, from dairy doe and ewe milk are now available with high quality in the world but not in Ethiopia. Ethiopia imports the main doe and ewe milk product cheese from Mediterranean countries where doe and ewe milk cheese is popular. Doe and Ewe milk cheese was originated in Mesopotamia.

The manufacturing technology of doe and ewe milk cheese is similar to that of cow cheese with little modification but the product cheese has significant difference both in composition and quality from that of cow cheese.

Cheddar cheese originated many decades ago in the little village of Cheddar, England, from which it spread throughout the world. Cheddar is crumbly and has a pronounced sharp, acid flavor and a higher salt content. Cheddar cheese may not be legally made from goat milk, because the term "Cheddar cheese" has originated from cheese made only from cow milk. However, Cheddar cheese can be and has been manufactured using doe and ewe milk, even if the latter has some problems of attaining the same level of moisture content as well as the firmness in texture of the cheese due to its naturally soft curd body formation of doe and ewe milk. The manufacturing procedure for doe and ewe milk Cheddar cheese has been adapted from that of cow milk cheese. Cheddar cheese from doe and ewe milk had higher moisture and protein and lower fat content than from its cow milk. The HACCP System is a logical, scientific approach to control safety problems in food production in our case for dairy industries.

Finally a successful dairy doe and ewe milk cheese industry cannot be established without the highest possible levels of cooperation among doe and ewe milk breeders, milk producers, and cheese and other dairy doe and ewe milk product manufacturers, distributors, and retail outlets. Effective communication of the basic information on production and consumption ecosystem is essential to sustainable dairy doe and ewe industry.

2.5 Doe and Ewe Milk Cheese Processing

Large numbers and many different varieties of Doe and Ewe milk cheeses are produced worldwide, depending on diversity of locality, milk composition, and manufacturing techniques. Doe and Ewe cheese would be expected to vary in composition due to the high variation in the seasonal composition of milk, modifications of manufacturing procedures, and multitude of aging time and conditions (Godina, 1985 and Park, 1990).

Much of the varietals difference among cheeses is attributed to the nature of physical and chemical changes during ripening which are influenced by the cultures, chemicals, or flavor ingredients added to the curd during manufacturing (Loewenstein *et.al*., 1980).

Doe and Ewe milk cheese was originated in Mesopotamia. The milk was probably made into soft cheese first and then hard and ripened cheeses later. Caprine milk cheeses were developed later in the Mediterranean basin countries, such as Turkey, Greece, Syria, Israel, Iraq, and Iran (Kosikowski, 1986). Many of these countries emerged as very large producers, consumers, and major exporters of various types of Doe and Ewe milk cheeses.

Cheese making in Africa is largely dictated by tradition. Due to shortage of milk, cheese production is expensive and powdered milk and cheese may be imported. The cheese produced is generally consumed very soon after manufacture, primarily because of the poor shelf life under ambient conditions. The problems are further compounded by the fact that during periods of surplus milk production the prices for milk, butter and cheese are considerably lower than in periods of lower milk production. Rapid population growth, crippling economic problems and political turmoil in many African countries have reduced living standards and affected food availability causing widespread protein deficiencies and malnutrition (FAO, 2003).

Table 2.3 Total Cheese production (Metric Tonnes) in African countries

Country	Production 1994	Production 2003
Algeria	1045	2000
Angola	1007	1007
Botswana	1498	5000
Egypt	333950	498000
Eritrea	216	Na
Ethiopia	4600	6000
Kenya	210	Na
Mauritania	1664	2000
Morocco	6947	8000

Namibia	70	Na
Niger	12064	15000
Nigeria	7022	8000
South Africa	38000	38000
Sudan	72479	152000
Tanzania	1200	3000
Tunisia	7060	14000
Zambia	1069	1069
Zimbabwe	5197	2000

Source: (FAO, 2003) na, not available

Most Doe and Ewe milk cheese varieties, which are consumed fresh, are set by an acid (hydrochloric, lactic, vinegar, lemon, lime, and so on) coagulation process, whereas cheese varieties consumed after ripening are generally made by the enzyme (rennet, chymosin) setting process.

Table 2.4 Traditionally produced cheese varieties in Africa

Name of Cheese	Type	Source of milk	Country
Aoules	Hard	Doe	Algeria
Ayib	Soft	Butter	Ethiopia
Braided	Semi-hard	Cow, doe or ewe	Sudan
Domiati	Soft	Buffalo	Egypt
Fromage	Semi-hard	Cow	Madagascar
Fromage blanc	Soft	Skimmed	Madagascar
Gybna beyda	Soft	Cow, doe or ewe	Sudan
Karish	Soft	Cow	Egypt
Laban Rayeb	Soft	Cow	Egypt
Mashanza	Soft	Cow	Congo
Mudaffara	Semi-hard	Cow	Sudan
Wara	Soft	Cow	Nigeria
Wagashi	Soft	Cow	Benin, Mali, Nigeria
Wagassirou	Soft	Cow	Benin

Source: O'Connor, 1995

2.5.1 Manufacturing Technology

- **Preparation of Doe and Ewe milk for cheese manufacture**

Because a good cheese is made only from good-quality milk, (Le Jaouen,1987) described that good cheese-making milk must be quality milk and must meet the following criteria: (i) it must be free of any visible impurity; (ii) it must not present any abnormal taste or odor; (iii) its acidity must be in the vicinity of or only slightly higher than that of milking time, unless it has been subject to a ripening period in which the lactic acid producing bacteria have been allowed a period of time to acidify the milk; (iv) the naturally occurring lactic acid producing bacteria and or yeasts or the cheese starter culture bacteria that can be added to the milk must be able to survive and reproduce to the proper numbers in the milk; (v) the milk must contain no foreign substances such as antibiotics, antiseptics, cleaning products, and so on; and (vi) the milk must not be contaminated by either pathogenic microorganisms or by microorganisms that may prove undesirable for the production of cheese.

- **Processing Methods**

Soft Doe and Ewe Milk Cheese

The Doe and Ewe milk cheese making consists of the following nine basic steps (64): (a) filtering of the milk; (b) renneting, sometimes preceded by acidification; (c) coagulation of the milk; (d) placing of the curds into cheese moulds, sometimes preceded by pre-draining; (e) draining, sometimes interrupted by turning the cheeses over; (f) molding; (g) salting; (h) drying; and (i) ripening (Godina, 1985).

Semi-Hard and Hard Doe and Ewe Milk Cheese

Semi-hard or hard Doe and Ewe milk cheese varieties such as Monterey Jack, Gouda, Cheddar, blue, and Camembert cheeses can be manufactured. In the United States, a significant volume of Monterey Jack Doe and Ewe cheese is commercially produced and marketed.

Manufacturing procedures of Monterey Jack Doe and Ewe milk cheese routinely performed at the University dairy processing pilot plant of the Georgia Small Ruminant Research and Extension Center (GSRREC), Fort Valley State University, GA, U.S.A., is described as the following detailed protocol: The bulk milk from its mixed herd Doe and

Ewe is transferred to the vat pasteurizer. The milk is pasteurized at 62.8°C (145°F) for 30 min. The cheese is manufactured according to the modified procedure of well documented processing methods (Kosikowski and Mistry, 1977). Each batch of cheese is made using between 135 and 170 L of milk maintained at 88°F (31°C) in a 60-gallon (227 L) cheese vat. Lyophilized mesophilic direct vat set starter culture (R704, 50 units, Chr. Hansen, Inc., Milwaukee, WI) and 18 ml of single-strength rennet (Chymax; Chr. Hansen, Inc., Milwaukee, WI) are added to the milk and then allowed to coagulate. The curds are cut using 1.6 cm wire knives and allowed to heal for 5 minutes. The temperature is gradually raised to 39°C (102°F) over 30 minutes and the curds are cooked until firm for about 45 to 60 minutes. Two-thirds of the whey is drained, and warm water (31°C) is added to the vat to wash the curds and to bring the temperature of the whey to 88°F (31°C). The curds are soaked with the water for 5 minutes before the whey is completely drained. Curds are placed into 6 x 6 inch (15.24 x 15.24 cm) Wilson hoofs and pressed at 40 psi overnight at room temperature in a vertical cheese press (Pneumatic Press, Kusel Equip. Co., Watertown, WI).

Cheeses are removed from the molds, cut into disks 5.08 cm (2 inches) in height, and vacuum packed in plastic pouches (FreshPak 500 vacuum pouches, Koch Supply, Kansas City, MO) using a vacuum packager (Koch Ultravac 250, Koch Supply, Kansas City, MO); they are then stored at 4°C in a walk-in cooler for six weeks before marketing.

Cheddar Cheese Made from Doe and Ewe milk

Cheddar cheese originated many decades ago in the little village of Cheddar, England, from which it spread throughout the world (Kosikowski, 1977). English Cheddar is crumbly and has a pronounced sharp, acid flavor and a higher salt content. Its American counterpart is more cohesive and waxy in texture with a generally bland flavor (Kosikowski, 1977). Strictly speaking, Cheddar cheese may not be legally made from doe or ewe milk, because the term “Cheddar cheese” has originated from cheese made only from cow milk.

However, Cheddar cheese can be and has been manufactured using Doe and Ewe milk, even if the latter has some problems of attaining the same level of moisture content as well as the firmness in texture of the cheese due to its naturally soft curd body formation.

Nevertheless, the doe and ewe cheddar cheese has been made from caprine milk including at the GSRREC, Fort Valley State University, Georgia, and other places. The manufacturing procedure for doe and ewe Cheddar cheese has been adapted from that of cow milk cheese.

2.5.2 Basic Composition and Yield

In a study of nutritional evaluations of more than 30 varieties of commercially manufactured doe and ewe milk cheeses from 11 states of the United States, most varieties of doe and ewe milk cheese were shown to have higher moisture contents compared to corresponding or similar types of cow cheese. Cheddar cheese from doe and ewe milk had higher moisture and protein and lower fat content than from its cow milk counterpart listed in the Agricultural Handbook No. 8-1 (Sanders, 1969).

Yields of cheese are dependent on manufacturing techniques in different locations, procedures, and the compositions of milk used. Due to a multitude of doe and ewe milk cheese processing methods in various parts of the world and with a significant variation in milk composition, there are wide variations in the yield of doe and ewe milk cheese (Price, 1952).

The Doe and Ewe milk cheese industry will never be able to compete with the cow cheese counterparts in terms of total volume of production, due to the lesser amount of milk production and seasonal milk supply. This inherent species-specific disadvantage of the Doe and Ewe cheese industry necessitates the exploration of some alternative solutions or technological development to enhance yield and quality of doe and ewe cheeses. These technologies are ultra filtration technology in doe and ewe milk cheese manufacture, freezing doe and ewe milk cheese or pre-cheese and fortification of doe and ewe milk cheeses (Kosikowski, 1977; Kosikowski, 1986).

2.5.3 HACCP Implementation Plan

The HACCP System is a logical, scientific approach to controlling safety problems in food production. There are five preparatory steps for an HACCP plan, and there are seven HACCP principles.

The Hazard Analysis and Critical Control Points (HACCP) plans are implemented in most modern food processing companies. Many local and individual dairy processing plants should also implement their own HACCP plans by adapting their own specific setup and conditions to ensure the food safety of their products for consumers.

2.5.4 Marketing and Its Challenges

Worldwide demand for doe and ewe milk products has been increasing, and future demand is very promising. The success of doe and ewe milk cheese industries will be heavily dependent upon the establishment of high-producing milking doe and ewe milk herds, production of high-quality milk, improved and carefully controlled cheese making and ripening techniques, appropriate packaging, and cost consciousness in the production of the final doe and ewe milk products (Haenlein, 1992). Proper distribution and packaging of doe and ewe milk cheese is the most integral element in expansion of the market for cheese. Attractive packaging of cheese is becoming a necessity for competing with cow milk cheese (Loewenstein *et.al.*, 1980).

A successful doe and ewe milk cheese industry cannot be established without the highest possible levels of cooperation among doe and ewe breeders, milk producers, cheese and other dairy doe and ewe product manufacturers, distributors, and retail outlets. Effective communication of the basic information on production and consumption ecosystem is essential. The consumer must be sold on the idea that doe and ewe milk cheese is something special perhaps through creative packaging and shapes of the products, and especially through its unique flavor. The survival and sustainability of the doe and ewe milk industry is also highly dependent on the extent of supports from government, industry, and academia. Cooperative and friendly supports for the promotion of consumption of dairy doe and ewe products and its industry are crucial for its survival (Park, 1992).

CHAPTER THREE

3. Materials and Methods

3.1 Source of Materials, Sample Collection and Transportation

Thirty seven liters of fresh doe and ewe milk were collected from Arsi Negele particularly from Langano area and Kofele particularly from Ashoka (A village 15 km from Kofele) in sterilized plastic containers in two batches. The samples were immediately placed in a cool box with ice packs and transported to Addis Ababa University Food Engineering laboratory. The starter culture and rennet enzyme were pre-arranged.

3.2 Sample Preparation and Storage

The transported raw milk was stored in the refrigerator below 4^0C for two days until subculture is prepared and raw milk proximate analysis was made. Doe and ewe raw milk was tested for: protein, fat, total solids and pH. 5 liters of each 100% doe and 100% ewe milk sample and their mix ratio was prepared at the following ratios 25:75; 50:50; 75:25. This mix ratio was chosen according to the research finding entitled "Introduction to food process modeling and optimization" described by Mallatou and Voutsinas (1994). Each sample was pasteurized at 71^0C for 15 seconds. Sub culture was then prepared using one liter of their mix preceding standard procedure.

Each batch of milk samples and processed cheese was coded as follow for data analysis purpose:

- Five liters of 100% raw doe milk = Sample 1
- Five liters of 100% raw ewe milk = Sample 2
- Five liters of 25% raw doe and 75% ewe milk = Sample 3
- Five liters of 50% raw doe and 50% ewe milk = Sample 4
- Five liters of 75% raw doe and 25% ewe milk = Sample 5
- Cheddar cheese made from 100% raw doe milk = Sample 6
- Cheddar cheese made from 100% raw ewe milk = Sample 7
- Cheddar cheese made from 25% raw doe and 75% ewe milk = Sample 8
- Cheddar cheese made from 50% raw doe and 50% ewe milk = Sample 9

- Cheddar cheese made from 75% raw doe and 25% ewe milk = Sample 10
- Cottage cheese made from 100% raw doe milk = Sample 11
- Cottage cheese made from 100% raw ewe milk = Sample 12
- Cottage cheese made from 25% raw doe and 75% ewe milk = Sample 13
- Cottage cheese made from 50% raw doe and 50% ewe milk = Sample 14
- Cottage cheese made from 75% raw doe and 25% ewe milk = Sample 15

3.3 Materials Equipments and Chemicals

In this experimental thesis the following materials and chemicals were used: Doe milk, Ewe milk, Small scale cheddar cheese processing unit operation, Pasteurizer, Incubator, Stove, Refrigerator, pH meter, Thermometer, Ice box, Flask, Glove, Sterilized bottles, Thermostat, Auto clave, Stop watch, Cheese knives, Stirrer, Sieve, Cheesecloth, Moisture analyzing equipment and Chemicals like Rennet, Lactic acid bacteria, Cleaning agent and Analytical reagents.

3.4 Process Technology of Cheese

3.4.1 Sub Culture Preparation

One liter milk from doe and ewe mix was heated gently in 1 liter glass beaker with constant stirring up to 93^0C. Then the milk was cooled quickly by immersing the beaker in cold water carefully. When cooled to 23^0C, the dried culture was mixed to a paste with a tea spoonful of the milk and added to the rest. Then the beaker was covered and stored at 21^oC and left over night then it was stored in a refrigerator. The mother culture of about 25ml was added to one liter boiled and cooled milk. Sub culture method for cheese processing was adopted from the industrial Food technology equipment instruction manual.

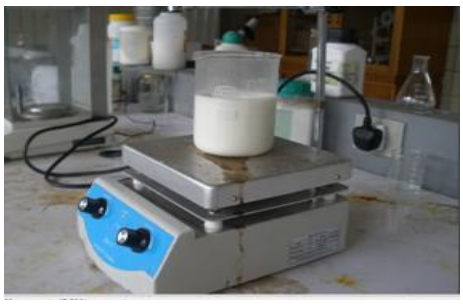


Fig 3.1 Sub Culture Preparation

3.4.2 Cheddar Cheese Processing Technology

Cheddar Cheese was prepared using the method described by Kosikowski (1977). Five liters of each samples of milk was used in the manufacturing of cheddar cheese consecutively. The sample milk was pasteurized and poured into processing vat to cool it to rennet temperature. The milk was inoculated with lactic acid bacteria as starter culture and allowed to incubate in the cheese vat at 30 ^{0}C for 40 min. After 35 min from the initiation of coagulation, Rennet was added. Curd strength was tested by immersion of a spatula into the curd after 15 min from Rennet addition and monitored every minute. After a clean cut was obtained approximately 35 min after enzyme addition the curd was cut using cheese knives. The temperature of the curd was gradually increased from 30 to 40 ^{0}C over a 30 min period with steady agitation. The curd cut was cooked at 40 ^{0}C for 60 min with agitation in every 5 min. After 60 min, 1/3 of the whey was drained. When the whey level becomes approximately 2.5 cm above the curd, draining was stopped and curd cuts were allowed to mat for 5 min. At this point, the jacket of the vat was filled with water at 38 ^{0}C and the remaining whey was drained. The curd mat was cut longitudinally to allow for whey draining. Whey sample obtained was tested for PH to measure the acidity in every 15 min. After 45 min cheese cut was turned over every 15 min, exposing new sides each time, until the end of the cheddaring process. The curd blocks was placed on a tray, cut and returned to the vat for salting and milling. Salt was added in equal portions in 5 min interval. The Cheese was mixed and allowed to rest for 10min before filling. Then pressed in a cheese press and dried at 12^{0}C while periodically turned over to allow for the development of a uniform structure (Walstra, 2006). Wet yield was calculated immediately after removal from the press. Each cut cheese was packed and stored. The above procedure was repeated two times for each sample.

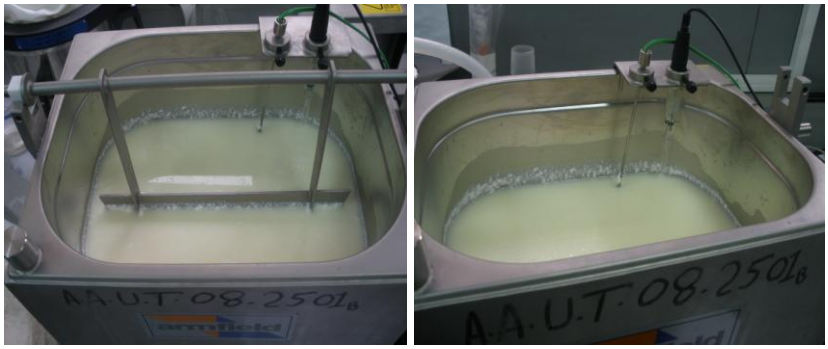


Fig 3.2 Cheese Vat (Model FT20, England, 2002) and Cheddar Cheese making Accessories

The following block diagram illustrates the procedure:

Figure 3.3 Process flow diagram of cheddar cheese manufacturing

3.4.3 Cottage Cheese Processing Technology

2 liters of milk was taken from each sampled mix ratios for cottage (Ayib) cheese making. Then the following procedure is followed for each five samples (O'Connor, 1993).

- Each milk samples was gradually heated to 65^{o}C until a distinct curd mass formed.
- Then the curd mass was cooled for one hour.
- The cheese curd and the whey were separated by pouring the curds and whey through a sieve allowing the whey to drain into a container. The curd retained was

mixed in the sieve to ensure that there are no pockets of whey which could lead to off-flavor and defects in the firmness of the curd.

- ❖ 100grams of salt was added to each sample to give a slightly longer shelf-life (in traditional procedure salt is not added to the cheese curd).
- ❖ Each cheese was stored in the refrigerator.

3.5 Equipment Lay Out of Cheddar and Cottage Cheese Processing Industry

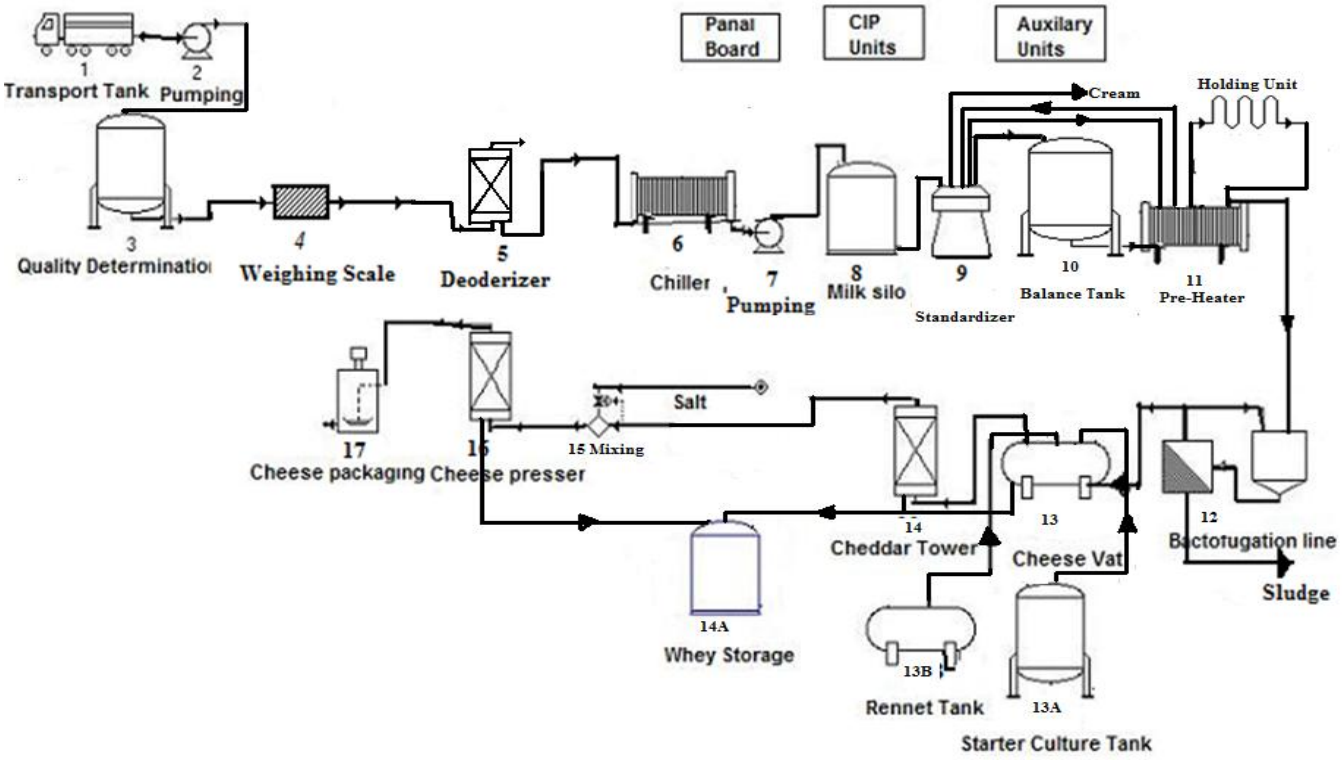


Fig 3.4 Equipment lay out for the production of cheddar cheese processing industry

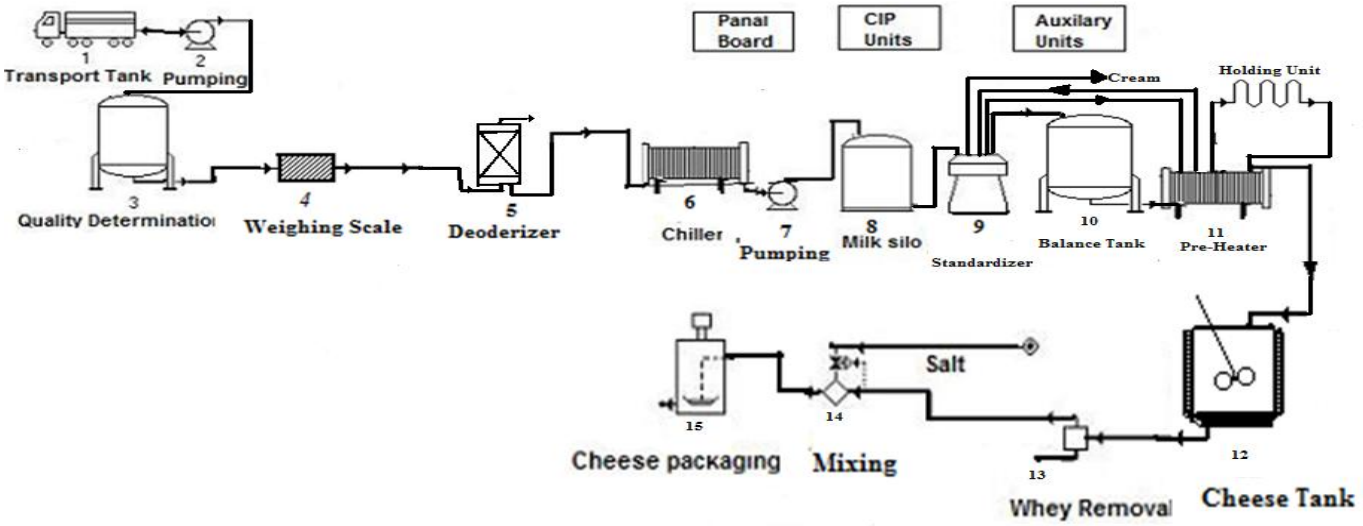


Fig 3.5 Equipment lay out for the production of cottage cheese processing industry

3.6 Analysis Methods

3.6.1 Proximate Analysis

3.6.1.1 Raw Milk and Cheddar Cheese

- **Determination of Fat by using Gerber method for Raw Milk**

Fat was determined at Holleta agricultural research institute. Each milk samples at temperature about 20°C was mixed thoroughly, taking care to minimize incorporation of air. The samples were allowed to stand for a few minutes to discharge any air bubbles and mixed gently again before pipetting. The following procedure was followed (O'Connor, 1995).

- 10 ml of sulphuric acid was pipetted into the butyrometer.
- 10ml of milk sample was pipetted into the butyrometer and milk stated to flow gently downs the inside of the butyrometer. It then rested on top of the acid.
- 1 ml of amyl alcohol was Pipetted and the neck of the butyrometer was cleaned with dry cloth.
- The butyrometer was stopped tightly using a clean, dry stopper and shaked and inverted several times until all the milk has been absorbed by the acid.
- The butyrometer was placed in a water bath at 65°C for 5 minutes.
- Then centrifuged for 4 minutes at 1100 rpm.
- The butyrometer was returned to the water bath for 5 minutes and Ensured that the water level is high enough to heat the fat column.
- The fat percentage was read by bringing the graduation mark to eye level.

- **Determination of Protein by using formaldehyde titration for Raw Milk**

The protein content of raw milk samples was determined by using formaldehyde titration method at Holleta Agricultural research institute. The principle behind this method is when formaldehyde is added to milk the free amino groups of the protein react with the carbonyl groups of formaldehyde causing the milk to become acidic. The acidity developed is related to the amount of protein present which may be measured by titrating with sodium hydroxide (NaOH) using phenolphthalein as indicator and the procedure is illustrated as follows (O'Connor, 1995).

- ❖ 10 ml of milk sample was placed in a white porcelain basin
- ❖ 0.4 ml of saturated aqueous potassium oxalate and 0.5 ml of 0.5% phenolphthalein solution was added and allowed to stand for 2 minutes and titrated with N/9 NaOH until a pink color is obtained.
- ❖ 2 ml of neutral 40% formalin was added which discharged the pink color.
- ❖ The titration was continued with N/9 NaOH until a pink color of equal intensity was again obtained.
- ❖ The number of ml of the N/9 NaOH used after the addition of the formalin multiplied by 1.74 gave the percentage protein in the milk.
- ❖ The formalin solution was made neutral by adding a few drops of phenolphthalein and then adding sodium hydroxide drop by drop until a faint pink color was obtained.

- **Determination of total solids by using oven-drying method for Raw Milk**

The total solid content of each raw milk samples was determined at Holleta agricultural research institute. The principle behind this method is a known weight of milk is dried at a constant temperature to a constant weight. The weight of the residue after drying is the weight of the total solids. The detailed procedure is illustrated as follows (O'Connor, 1995).

- ❖ The dish and the lid were dried in the oven at 102±2°C for 1 hour and allowed the dish with the lid on to cool to room temperature in a desiccator.
- ❖ The dish and the lid were weighed to the nearest 0.1 mg.
- ❖ The milk sample was warmed to 20±2°C and heated to 40°C to liquefy the fat, mixed gently and cooled to 20±2°C.
- ❖ 3 ml of the milk was pippetted into the dish and the dish was covered and weighed.
- ❖ Then the dish was uncovered and placed in a boiling water bath for 30 minutes and also Dried in the drying oven at 102± 2°C for 2 hours with the lid placed beside the dish.
- ❖ The dish was cover, removed from the oven and allowed to cool to room temperature in the desiccator and weighed and dried in the oven for 1 hour

as before. Cooled and reweighed. Repeated the drying until the difference in weight between two successive weightings is not more than 1 mg.

- ❖ Finally the total solids content, expressed as a percentage by mass is equal to:

$$\frac{m_2 - m_0}{m_1 - m_s}$$

Where: $\mathbf{m_2}$ is the mass of the dish, lid and dried test portion (g).

$\mathbf{m_0}$ is the mass of the dish and lid (g).

$\mathbf{m_1}$ is the mass of the dish , lid and test portion (g). and

$\mathbf{m_s}$ is mass of the sample (g).

- **Determination of Moisture content and total solid for Cheddar Cheese**

For each analysis a representative cheese sample of 100 g was collected from the cheeses after 5 days of production. The moisture content of each cheese samples was measured directly by using digital moisture Analyzer equipment model MB45 and total solid content by using oven drying method following (Method 926.08; AOAC, 2000).

- **Determination of Fat content for Cheddar Cheese**

To determine the fat content soxhlet extraction method was used at EHNRI chemistry laboratory. The principle behind this method is fat is extracted with ether from dried samples in a soxhlet apparatus, and the other is evaporated from the extraction flask. The amount of fat is calculated from the difference in weigh of the extraction flask before and after extraction (Method 933.05; AOAC, 2000).

- **Determination of protein content for Cheddar Cheese**

Protein content of the cheese samples was determined by Tecator method at EHNRI chemistry laboratory. The principle is all nitrogen is converted to ammonia by digestion with a mixture of concentrated sulfuric acid and concentrated orthophophoric acid containing potassium sulfate as a boiling point raising agent and selenium as a catalyst. The ammonia released after alkalinization with sodium hydroxide is steam distilled into boric acid and titrated with sulfuric acid (Method 920.123; AOAC, 2000).

3.6.2 Microbiological Analysis

3.6.2.1 Cheddar Cheese from Doe and Ewe Milk

The bacterial count refers to the number of aerobic microorganisms that develop at specific temperature and is expressed as a number of colony forming units (cfu) per gram. The microbiological analysis was conducted at EHNRI laboratory following the proceeding procedures. Each five samples of cheeses were analyzed in triplicate at 0 days of production. Aerobic Plate Counts (APC), Staphylococcus aureus and mold and yeast was determined by following standard procedure of EHNRI laboratory.

- **Sample preparation**

25g of each cheese samples was transferred to 225 ml of diluents in a flask for the stomacher used to make 10^1 dilutions (the first dilution) then mixed with shaker. The first dilution was mixed by shaking and then pipette 1ml of it into a tube (labled10^2) containing 9 ml of normal saline and then mixed carefully by aspirating 10 times with a pipette. From the 10^2 dilution, 1ml was also transferred with the same pipette to the tube (labled10^3) containing 9ml of the diluents and mixed with a fresh pipette. The results was rounded to two significant figures and expressed it as a number between 1.0 and 9.9 multiplied by 10^x where x is the appropriate power of 10. The result was expressed in cfu per g (Annex 1, pp 84).

- **Determination of Aerobic Plate Counts (APC) in the cheese samples**

The aerobic colony count estimates the number of viable aerobic bacteria per gm or ml of a product. A portion of the diluted sample mixed with a specified agar medium and incubated under specific temperature for 48 hr. It was assumed that each viable aerobic bacterium was multiplied under these conditions and gave rise to colonies. Plate count agar was used for the enumeration of Aerobic plate counts in the cheese samples (Annex 1, pp 84).

❖ **Determination of Staphylococcus aureus in the cheese samples**

Certain staphylococci produce enter toxins which cause food poisoning. This ability to produce enter toxins, with few exceptions, is limited to those strains that are coagulase positive, and /or produce a heat stable nuclease.

This method determines the presence of *S. aureus* by plating known quantities of cheese sample onto a selective agar. The media used was Mannitol salt agar and the diluents peptone water (Annex 2, pp 87).

❖ **Determination of Mold and Yeast in cheese samples**

In this method the numbers of viable aerobic mould and yeast per g of product was estimated. A portion of the cheese homogenate is mixed with a specified agar medium and incubated under specific conditions of time and temperature. It was assumed that each viable aerobic mould/ yeast was multiplied under these conditions and gave rise to a colony. The media used was potato Dextros Agar and diluent was peptone (Annex 3, pp 88).

Fig 3.6 Microbiological Analysis

3.6.3 Physico-Chemical Analysis

3.6.3.1 Viscosity and pH

Viscosity of raw milk was measured by using a viscometer model SV – 10, 2005 at 25^0C before processing in Food Engineering laboratory and was expressed in mPas. The pH of raw milk and each sample cheese milk was measured with a pH meter at the beginning of processing and number of intervals at ripening, cooking and cheddaring stages of cheese making by using digital pH -meter model pH Tester 10 Automatic temperature compensator.

- **Ripening stage**

Milk ripening is the second stage in the cheese-making process after pasteurization. Milk received for making cheese was added with the starter culture at 30^0C. The initial pH of each cheese milk samples was measured and four pH measurements were made during milk ripening stage at 0, 10, 20 and 30 min after the addition of Lactic acid bacteria.

- **Stirring / scalding /cooking stage**

Once the curd was cut, the cooking of curd was started with gentle stirring, with the temperature allowed to rise from 30^0C to 40^0C and then held at this temperature for 30 min. During the cooking for each sample, pH measurements were made with periodic measurements at 10 min intervals.

- **Cheddaring stage**

At this stage the curd fused together and forms texture. The block of curd is turned periodically and matted to expel the moisture further, develop the desired texture and to cause the cheese to fuse together. The matted cheeses was turned every 15 min and total cheddaring period lasted about 100min. At this stage pH measurements were made with 20 min intervals because the time of cheddaring is longer than the others and the pH of the whey drained is measured rather than the solid cheese pH.

3.6.3.2 Texture

Texture analysis was performed to analyze the hardness and fracturability of the cheese samples using TS Texture analyzing equipment LLOYD instrument, TA plus Ametek, UK 2007. Each Cheddar cheese samples were analyzed at 5^0C.The test method used was compression and the sample size was 50 g, Load of hardness measurement was zero N. Cross head speed was 20 mm/min. The result was expressed in N/g. The probe used was cheese cutting jig.

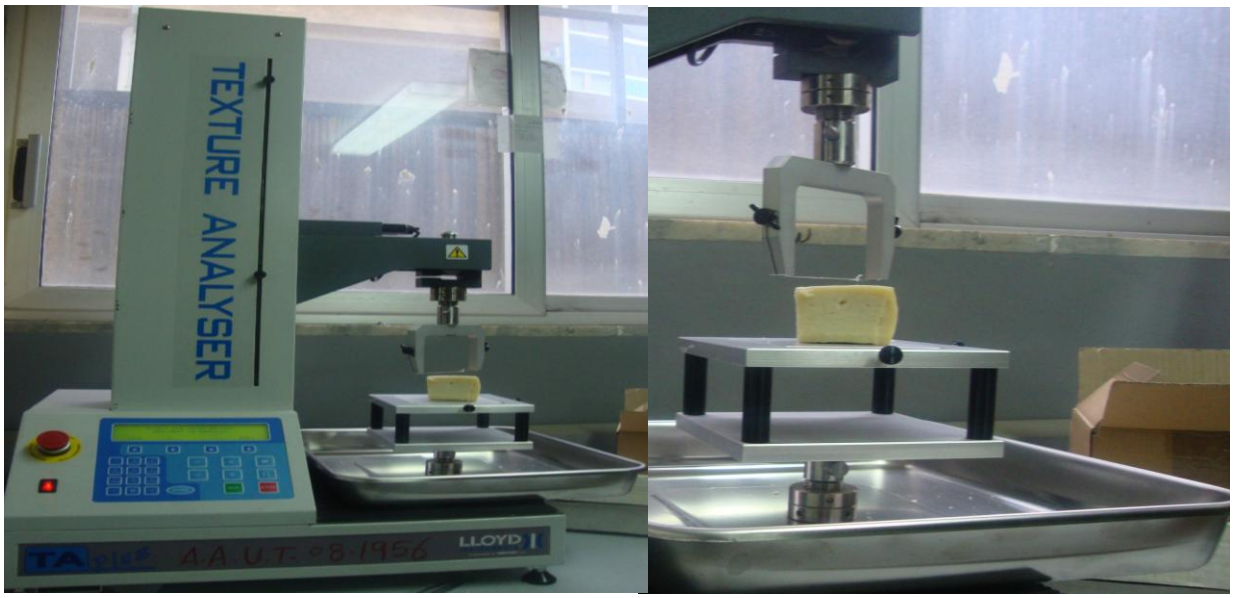


Fig 3.7 Texture Analyzer (LLOYD Instruments, TA plus Ametek, UK 2007)

3.6.4 Yield of Cheddar and Cottage Cheese

The yield of the cheese making process is usually defined as the mass of cheese produced from a given mass of cheese milk. It is expressed in units of kilograms of cheese per 100 kg of milk. Cheese yield is one of the most economically important aspects of cheese manufacturing. The cheese yield was measured using balance beam after the cheese making process (Kosikowski, 1977). The adjusted yield was calculated based on the actual cheese yield based on the following formula.

- Adjusted yield = Actual yield x $\frac{100 - (\%\ \text{Actual moisture} + \text{Salt})}{100 - (\%\ \text{Desired moisture} + \text{salt})}$

Cheese yield efficiency was calculated by dividing the actual cheese yield by percent total of fat, protein or total solids in milk.

Component (protein, fat and total solids) recovery was calculated as the weight of the component in the cheese divided by the original weight of the component in the milk.

$$\text{Component recovery \%} = \frac{\text{\% component in product x quantity of product}}{\text{\% component in milk x quantity of milk}} \times 100$$

3.6.5 Sensory Evaluation

Each cheese samples was subjected to sensory evaluation using 12 panelists. Sensory attributes of appearance, color, texture, flavor, saltiness, taste and over all acceptability was considered by the panelists using an evaluation sheet attached in the appendix. Each attribute was scaled by using a 9-point structured hedonic scale (1 – 'extremely disliked' to 9 – 'extremely liked').

3.7 Statistical Analysis

The experiment was repeated two times and duplicate sample was analyzed during each repetition. The data obtained was statically analyzed by using Statistical Package for Social Scientists (SPSS 17th Version) to determine the best quality cheese made with those mix ratios.

A factorial arrangement in a completely randomized design was set to see the effects of mix ratios on the qualities of cheddar cheese and suggest the optimum mix ratio of goat to sheep milk to achieve the best product characteristics. Mix ratio was the independent variable selected for determination of best quality. Analysis of variance was done and level of significance was set at 5%.

CHAPTER FOUR

4. Results and Discussion

4.1 Proximate Analysis

4.1.1 Raw Milk and Cheddar Cheese

Proximate analysis results of raw doe, ewe and mix ratios milk are shown in Table 4.1. Samples were taken from raw milk for protein, fat and total solid determination. The result of this milk samples are illustrated in the following table.

Table 4.1 Composition of raw doe, ewe and their mixture of milk samples (w/w)

Samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Protein (%)	2.89	4.82	4.41	4.13	3.85
Fat (%)	4.3	6.0	5.6	5.1	4.8
Protein/ Fat	0.67	0.80	0.79	0.81	0.80
Total solid (%)	12.62	17.40	15.89	15.00	13.90
Density (g/ml)	1.029	1.036	1.034	1.032	1.032

Where: Sample 1 is 100% doe milk; sample 2 is 100% ewe milk; sample 3 is 25% doe and 75% ewe milk; sample 4 is 50% doe and 50% ewe milk and sample 5 is 75% doe and 25% ewe milk.

Proximate analysis results of cheddar cheese for each type of milk are shown in table 4.2. These include moisture content, total solid, fat, protein and lactose. Based on these data effect of mixing of doe to ewe milk with different proportion is justified following the result table.

Table 4.2 Composition of Cheddar Cheese (w/w)

Sample	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Moisture content (%)	27.77	35.29	34.06	35.76	34.79
Total solids (%)	42	47.1	44.7	44.3	43.9
Fat (%)	54.8	30.1	25.3	35.4	44.5
Protein (%)	21.6	23.7	22.8	23.9	21.1
Lactose (%)	1.2	0.9	1.1	1.0	1.0
Ash (%)	1.4	1.7	1.6	1.5	1.5

Where: Sample 6 is cheddar cheese made from 100% doe milk; sample 7 is cheddar cheese made from 100% ewe milk; sample 8 is cheddar cheese made from 25% doe and 75% ewe milk; sample 9 is cheddar cheese made from 50% doe and 50% ewe milk and sample 10 is cheddar cheese made from 75% doe and 25% ewe milk.

The moisture content of cheeses made from all samples of milk is in the range expected to be for cheddar cheese (<38%) (Walstra, 2006) and also there is significant difference in moisture content of 100% doe milk than other mix ratios. The cheeses made from 100% doe milk had the lowest moisture content (27.77) of all the cheeses. The observed differences in moisture contents of the cheeses were observed because of the difference in protein to fat ratio of milks used. As seen from table 4.1, the ratio of protein to fat in 100% doe milk was 0.67 compared to 0.80, 0.79 and 0.81 in other mix ratios. This is in agreement with that the moisture content of cheddar cheese increased as the ratio of protein to fat content of the cheese milk was increased. Based on their moisture content 100% doe milk cheese had the lowest moisture content implies best quality because lower moisture content of cheese helps the cheese to have longer shelf life.

The average protein content of the five cheeses determined did not differ significantly (Table 4.2). The protein content of all cheeses was within the range 21.1 to 23.9. This is almost similar with the cheese made from 100% doe milk purchased from Bambies Super market imported from Greek (25%) taken as reference for protein and fat content. The total solid and lactose content of cheddar cheese determined did not differ significantly and not considered.

The fat content of cheddar cheeses prepared from these milks differs statistically. The highest fat content (54.8%) was in cheeses made from 100% doe milk (Table 4.2), and this is in agreement with the value of fat content of the reference cheese (50%). There was a decrease in fat content of cheese with the composition of sheep milk mixed in each milk samples and the lowest fat content was recorded for cheddar cheese made from 25% doe and 75% ewe milk (25.3%). For export market cheese with lowest fat content is preferable because nowadays fat free foods are desired by developed countries. But for developing countries like Ethiopia which didn't satisfy basic need from food; fat is essential. By compromising the above situation in between value which is not minimum or maximum (35.4%) was chosen as best cheese for this experimental work.

Generally from proximate analysis result 100% doe milk cheese was best quality interms of moisture content having longer shelf life. Protein, total solid and lactose content didn't create difference between cheeses. 50% doe and 50% ewe milk was best based on fat content.

4.2 Microbiological Analysis

4.2.1 Cheddar Cheese Made from Doe and Ewe Milk

The result of the microbiological analysis for Cheddar cheeses made from those mix ratios are given in table 4.3. All determinations were made in triplicate and expressed as colony-forming units (cfu) per gram of sample.

Table 4.3 Microbiological analysis result of cheddar cheeses

Samples	**Microbiological Analysis results (cfu/g)**			
	APC (Aerobic plate count) at 30^0C/72 h	*Staphylococcus Aureus* at 370/48hrs	Mold count at 25^0C/ 6 days	Yeast count at 22^0C/6 days
Sample 6	$1*10^3$	$1*10^2$	$3*10^4$	$2*10^4$
Sample 7	$1*10^1$	$2*10^2$	$1*10^5$	$3*10^4$
Sample 8	$2*10^2$	$2*10^2$	$4*10^3$	$6*10^2$
Sample 9	$1*10^2$	$1*10^3$	$8*10^2$	$5*10^2$
Sample 10	$1*10^3$	$1*10^2$	$6*10^2$	$4*10^2$
Reference range	$< 1*10^4$	$< 1*10^4$	$< 1*10^4$	$< 1*10^4$

The EU directives establish the maximum limits admissible for the milk and milk products of doe and ewe with the aim of upholding or improving the quality of milk and milk products to be sold or transformed (Fernandes, 2008). Comparing the results obtained, the mold and yeast counts for 100% doe and 100% ewe milk were found to be higher. This could be as a result of unhygienic condition during milk reception, transportation and processing. The results for APC and Staphylococcus for all mix ratios and mold and yeast count other than 100% doe and ewe milk cheese were below $1 * 10^4$. From microbiological analysis it can be concluded that all cheese made from all proportions did not exceed the limit and it is in acceptable range.

4.3 Physico- Chemical Analysis

4.3.1 Viscosity and pH

Viscosity and pH of raw milk was determined before processing and results are illustrated in table 4.4.

Table 4.4 Viscosity and pH of raw milk

Samples	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Viscosity (mPas)	1.66	3.04	1.70	2.01	2.67
pH	6.4	6.8	6.7	6.6	6.5

pH Change in Cheddar cheese making process

In cheddar cheese making process pH was measured to control the general cheese making process in the main steps. These steps were Ripening, stirring/Scalding/Cooking, cheddaring stages. The pH range has been grouped to show the three main stages milk ripening, cooking and cheddaring. Fig. 4.1, 4.2 and 4.3 shows a typical plot of pH change during cheese-making process. The figures demonstrate some differences in the pH change behavior between the different phases.

- **During Ripening Stage**

The initial pH of each milk samples is illustrated in table 4.4. Four pH measurements were made during milk ripening stage at 0, 10, 20 and 30 min after the addition of Lactic acid bacteria for each five cheese making process. During milk ripening period, pH was dropped from 6.8 to 6.1 in all mix ratios.

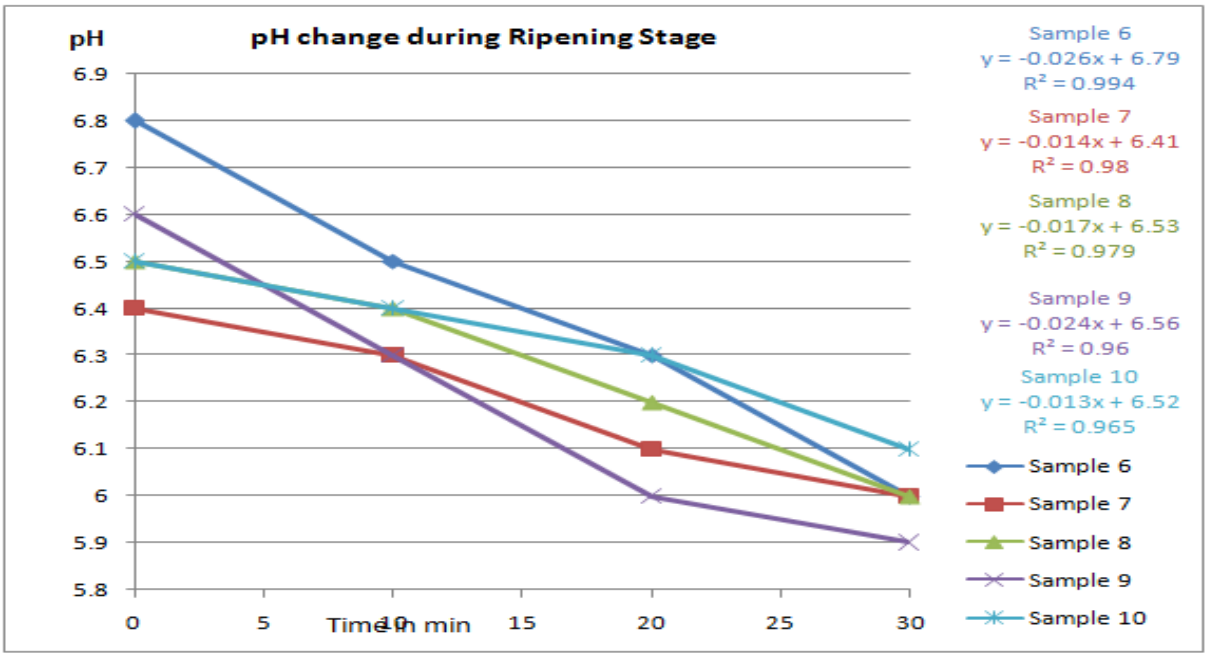


Fig 4.1 pH change with time during ripening stage

From figure 4.1; there was no difference in the rate of decreasing of pH between the five types of cheese during ripening.

- **During Stirring / scalding /cooking stage**

There was only slight pH change in this process. The sample pH measurements were made with periodic measurements at 0, 10, 20, 30 and 40 min intervals. The results are as follows.

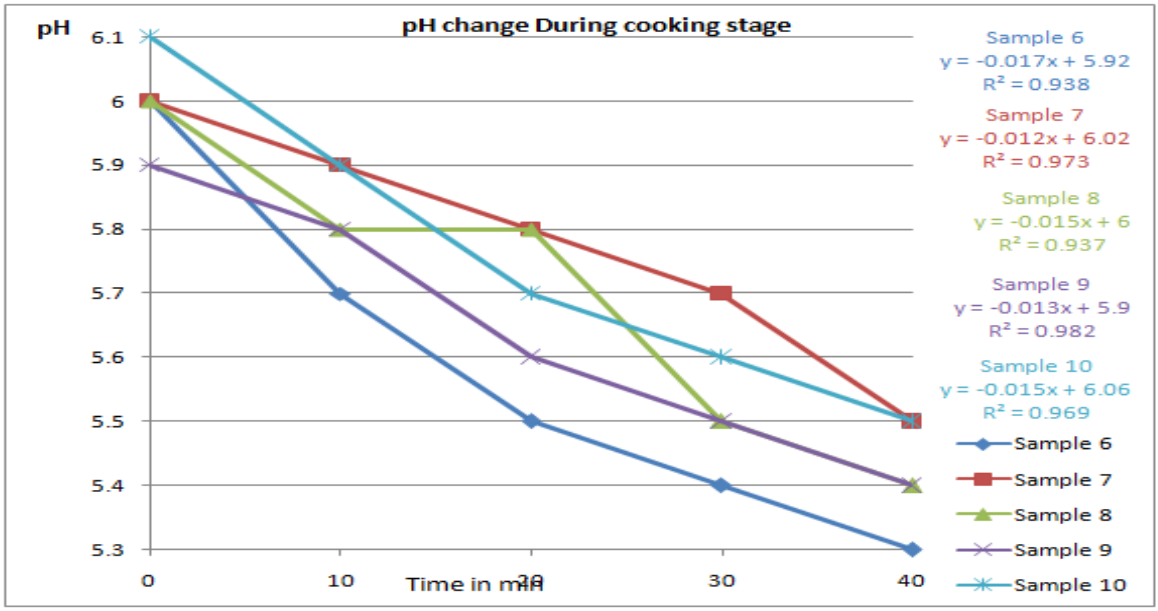


Fig 4.2 pH change with time during cooking stage

Generally it can be seen that in the first two stages, ripening and cooking, a linear change in pH with time in all five types of cheese was seen.

- **During Cheddaring stage**

The final pH at the end of this stage was in the range of 4.9 - 4.7 before passing the curd for milling and salting stages. pH was measured at 0, 20, 40, 60, 80 and 100 min of cheddaring stage.

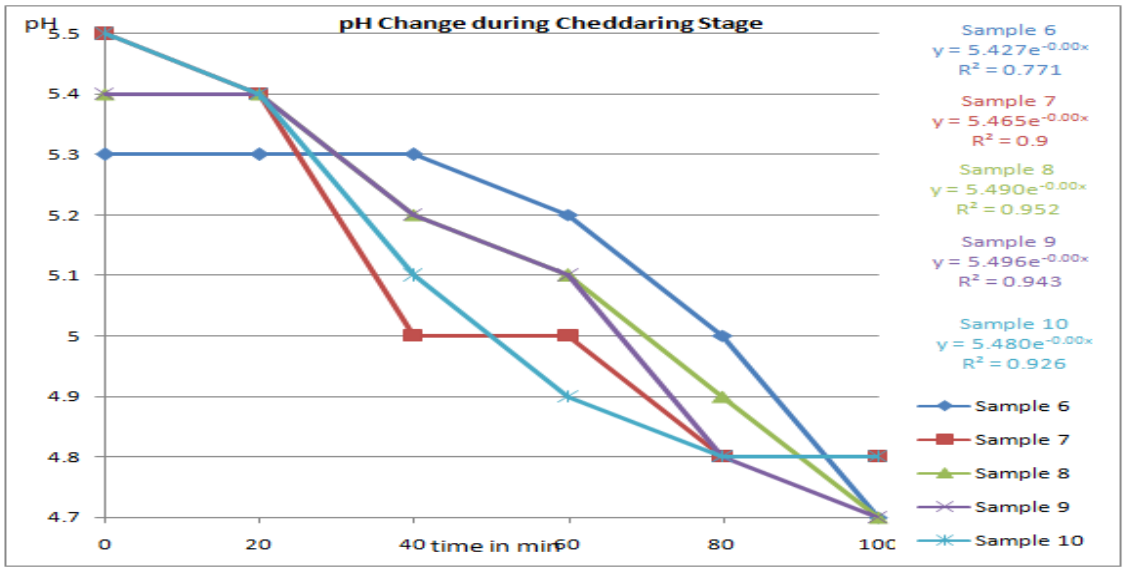


Fig 4.3 pH change with time during cheddaring stage

In the cheddaring phase the drop in pH was slow and the behavior was nonlinear with time again in all five types of cheeses. It is obvious from Fig. 4.1, 4.2 and 4.3 that the pH change profile in cheddaring stage was different from those in milk ripening and cooking stages, with the curves showing a nonlinear behavior. Slow change in the pH rate during this period result from most of the whey, which is drained, will carry away the soluble lactose with it. The shortage of lactose could thus reduce the activity of lactic acid bacteria and the acid production in the cheese. The higher the water content, the more the lactose in it and lactic acid present in the cheese which lowers the pH.

It can be also seen that there was a decrease in the pH of all cheeses starting from the ripening up to cheddaring stage. A similar trend in the pH of Cheddar cheese made from

cow milk was reported by Walstra (2006). During these stages, the decrease in pH was most rapid in 100% doe milk and slowest in that of 100% ewe milk. This difference in the rate of pH decrease resulted from lower buffering capacity of doe milk due to its lower protein content compared to that of ewe milk (Simos et al, 1991).

After cheddaring stage, the pH values of all cheeses become constant (4.7) which remained same there after 20 hours of drainage, without significant difference between the cheeses. Results obtained prove that 7-8 h was sufficient for development of acidity for all cheddar cheeses made in this study.

4.3.2 Texture

The results of textural examination calculated from the first cycle compression curves of fig 4.4, 4.5, 4.6, 4.7 and 4.8 are discussed as follow and specific conditions for the test is illustrated Table 4.5.

Table 4.5 Data for the process of Texture Analysis

Sample	Probe	Test type	Test mode	Preload/ stress (N)	Test speed (mm/min)
Cheese	Cheese cutting jig	Limit	Compression	0	21

- **Sample 6**

The following graph shows how the strain or extension changes with time when a viscoelastic material is subjected to a constant shear stress, followed by removal of the shear stress for sample 6; cheddar cheese made from 100% doe milk.

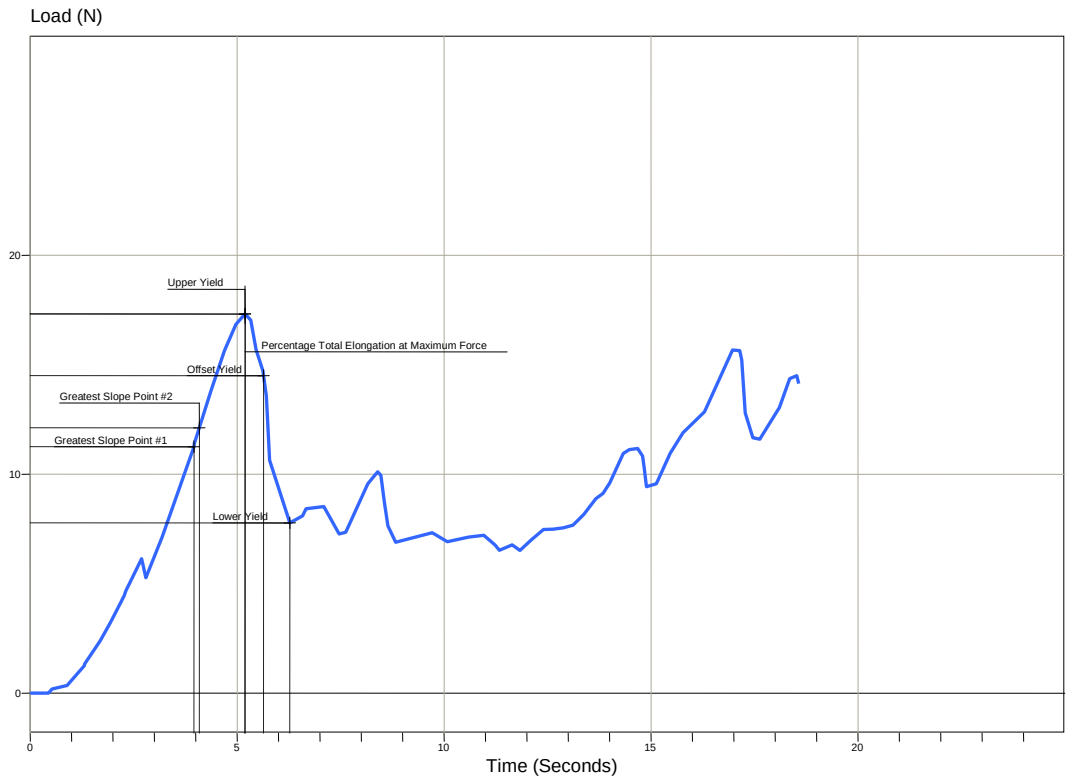


Fig 4.4 Graph of texture measurement of cheddar cheese made from 100% doe milk

Hardness: The hardness value is the peak force of the first compression of the product. As can be seen from the graph, the hardness load is 32.5N at time of 5.2seconds.

Therefore: **Hardness** = Load of Texture Analyzer / Mass of Cheese = 32.5N / 50 g = 0.65 N/g

Fracturability: The fracturability point occurs where the plot has its first significant peak where the force falls off during the probe's first compression of the Product. In the above graph the fracturability occurs at 7.825N load and at time of 2.9seconds. :

Fracturablity = Load of Texture Analyzer / Mass of Cheese = 7.825N / 50 g = 0.1565 N/g

- **Sample 7**

For sample 7; cheddar cheese made from 100% ewe milk.

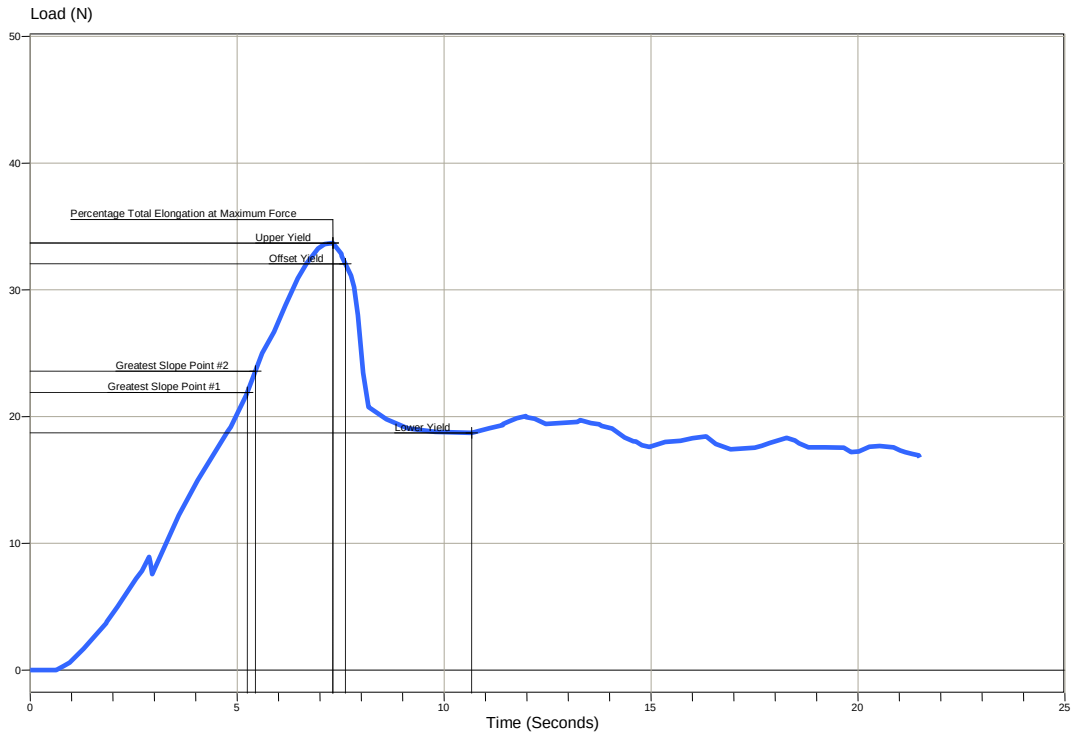


Fig 4.5 Graph of texture measurement of cheddar cheese made from 100% ewe milk

$$\textbf{Hardness} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{14.85\text{N}}{50\text{ g}} = 0.297\text{ N/g}$$

$$\textbf{Fracturability} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{3.9\text{ N}}{50\text{ g}} = 0.078\text{ N/g}$$

❖ **Sample 8**

For sample 8; cheddar cheese made from 25% doe and 75% ewe milk.

$$\textbf{Hardness} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{28.45\text{N}}{50\text{ g}} = 0.569\text{ N/g}$$

$$\textbf{Fracturability} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{7.445\text{ N}}{50\text{ g}} = 0.1489\text{ N/g}$$

❖ **Sample 9**

For sample 9; cheddar cheese made from 50% doe and 50% ewe milk.

$$\textbf{Hardness} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{22.65\text{N}}{50\text{ g}} = 0.453\text{ N/g}$$

$$\textbf{Fracturability} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{5.93\text{ N}}{50\text{ g}} = 0.1186\text{ N/g}$$

❖ **Sample 10**

For sample 10; cheddar cheese made from 75% doe and 25% ewe milk.

$$\textbf{Hardness} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{16.65\text{N}}{50\text{ g}} = 0.333\text{ N/g}$$

$$\textbf{Fracturability} = \frac{\text{Load of Texture Analyzer}}{\text{Mass of Cheese}} = \frac{4.35\text{ N}}{50\text{ g}} = 0.087\text{ N/g}$$

The above calculation for the hardness and fractrability of cheese show that as the percentage of doe milk in the cheese milk increased the force required to fracture the sample increased, i.e. the cheese tended to become less brittle. It is also evident from Table 4.6 that the hardness of the cheeses increased as the proportion of doe milk increased. The force at the point of fracture of the cheese made from 100% doe milk was significantly higher than that of the cheeses made from 50 or 25% doe milk, or 100% ewe milk, i.e. 100% doe milk cheese is less brittle than the other mix milk cheeses.

Table 4.6 Results for all samples

Results	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Load (N)	32.5	14.85	28.45	22.65	16.65
Hardness(N/g)	0.65	0.297	0.569	0.453	0.333
Fractrability (N/g)	0.1565	0.078	0.1489	0.1186	0.087
Stiffness(N/m)	5189.7	4053.7	4233	4579	5076
Young's Modulus(Mpa)	0.14828	0.13512	0.1378	0.14224	0.1467
Tensile Strength(Mpa)	0.02407	0.019237	0.02004	0.02256	0.0234
Stress at maximum load(Mpa)	0.02407	0.019237	0.02004	0.02256	0.0234
Stress at maximum Extension(Mpa)	0.011979	0.016098	0.01564	0.01489	0.0122
Strain at maximum load	0.28641	0.26294	0.27645	0.279882	0.28134
Strain at maximum Extension	0.87614	1.0019	0.9564	0.91238	0.86592

Table 4.6 demonstrates cheese made from 100% doe milk required higher compression to fracture than the other cheeses. The data also show that the cheeses differed significantly in hardness. The hardest cheeses were those made from 100% doe milk and the softest that made from 100% ewe milk. All other types of cheese had intermediate values. The higher the proportion of doe milk in the cheese milk, the harder the cheese; because of higher fat content of doe milk. From texture analysis it can be concluded that the hardest cheeses were those from 100% doe milk and the softest were from 100% ewe milk. Based on textural result 100% doe milk cheese was best quality cheese.

4.4 Yield of Cheddar and Cottage cheese

Cheese yield from each milk samples was measured directly using balance beam after the cheddaring process for cheddar cheese and five liters of milk sample was used to make one batch cheese. For cottage cheese 2 liters of milk sample was used to make one batch cheese. The following amount of cheese was obtained as illustrated in the table 4.7 below.

Table 4.7 Cheese yield from each sample

Sample	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Cheddar Cheese yield (kg)	0.66	0.88	0.75	0.72	0.69
Cottage Cheese yield (kg)	0.33	0.45	0.30	0.41	0.32

The result of different amount of addition of ewe to doe milk on the yield of cheddar and cottage cheese compared to cheeses made from 100% ewe or doe milk are shown in the above table 4.7. The table shows that the cheese yield differed significantly for all mix ratios. The mean yield of cheeses was 0.66kg and 0.88kg for 100% doe milk and 100% ewe milk for cheddar cheese and 0.33 and 0.45 for cottage cheese respectively; cheese yield for the other mix ratios of milk had intermediate values. It can be concluded that as percentage of ewe milk increased the yield increased, this is because of higher total solid content of ewe milk than doe milk. Based on cheese yield 100% ewe milk cheese had highest yield but milk yield of ewe is lower to compensate these lower yield of milk mixing of ewe milk to doe milk is taken as a better solution so intermediate value for there mix; 50% doe and 50% ewe milk was chosen as best quality interms of cheese yield and milk yield.

4.5 Sensory Analysis

After collection of all score sheet the results of each characteristic was added and divided by the number of participants (peoples who taste the product) and also the result (response) was fed to the SPSS software to get the final analysis of the data.

Table 4.8 Sensory Score Sheet result

Properties	**Summation of overall Score**	**Number of Participants**	**Average score**
Appearance	86	12	7.17
Taste	63	12	5.25
Flavor	102	12	8.5
Texture	98	12	8.17
Color	59	12	4.92
Saltiness	41	12	3.42
Overall Acceptability	100	12	8.33

Table 4.9 Sensory Analysis Result at initial day of manufacturing

Samples	Sensory qualities						
	Appearance	**Taste**	**Flavor**	**Texture**	**Color**	**Saltiness**	**Overall acceptability**
Sample 6	6.28[a]	4.18[a]	6.74[a]	6.82[a]	4.18[a]	3.83[a]	7.18[a]
Sample 7	6.08[a]	4.76[a]	7.09[a]	6.76[a]	4.41[b]	3.46[b]	6.84[a]
Sample 8	6.79[a]	4.69[a]	6.81[a]	8.60[a]	5.53[a]	3.48[a]	6.48[b]
Sample 9	7.25[b]	5.53[a]	8.81[a]	8.94[b]	4.40[b]	3.33[a]	8.98[a]
Sample 10	6.39[a]	4.99[a]	6.81[a]	7.01[a]	4.30[a]	3.25[a]	6.38[a]

[a-b] Means bearing the same letters in the same column are not significantly different at $P < 0.05$

The results of sensory assessment of the different cheeses are reported in table 4.8 and 4.9. Statistical analysis showed that the mean scores for body-texture, flavor, and appearance and over all acceptability for the five sets of cheese differed significantly. No differences were found between the mean scores for saltiness except 100% doe cheese were salty than the others. With regard to taste 50% doe and 50% ewe milk cheese had got the highest score with out significant difference. 25% doe and 75% ewe had got the highest score for color of cheddar cheese.

The results in table 4.8 indicate that the cheese made from 50% doe and 50% ewe milk had got highest scores for body texture than the other cheeses, as they had the characteristic texture of cheddar cheese with the typical almond shaped holes. Cheese made from 75% ewe milk rank the second highest score and there were no significant differences between the other cheeses.

Again with regard to flavor, the cheeses made from 50% doe and 50% ewe milk received the highest scores, with out significant difference. Cheeses made from milk containing 75 or 25% doe milk showed no difference in flavor.

None of the taste panelists detected an objectionable goaty flavor in any cheese even that made from 100% doe milk this is because the characteristic flavor components of cheddar cheeses are effective in covering the goaty flavor derived from doe milk.

Considering the overall acceptability the results in table 4.8 and 4.9 shows that the highest total scores were awarded to cheeses made from 50% doe and 50% ewe milk with significant differences between them than cheeses made from 100% doe and 100% ewe milk. No differences in over all acceptability were observed among cheeses made from 25% and 75% doe milk mix ratios.

The overall sensory results indicate that cheddar cheeses made from 50% doe and 50% ewe milk were superior in body texture, flavor and over all acceptability characteristics to the other mix ratios cheeses.

CHAPTER FIVE

5. Suggested Technology of Cheddar Cheese Processing

5.1 Material and Energy Balance

5.1.1 Material Balance

The system boundary is the first element which must be defined in the material and energy balance. In the case of this thesis, cheese making process, the system boundary starts at the pipe exit from the raw milk silo and ends with the process of cheese curd draining, salting and pressing system.

Auxiliary operations such as the supply of energy, chemical and water utilities will not be included in the material balance. For the process of cheese making the feed material is generally doe milk and ewe milk. As it can be concluded from the result and discussion part 50% doe and 50% ewe milk cheese is the best quality cheese so by taking the design basis 2000 liters of mixture of 50% doe and 50% ewe milk per day.

The basic components and typical mass fractions in 50% doe and 50% ewe milk are given in Table 5.1.

Table 5.1 Basic components of milk needed for the material and energy balance

Component	Fat	Lactose	Total Protein	Ash	Water
Mass fraction of raw milk (%)	5.1	4.82	4.13	0.95	86.3
Mass fraction of Cheese (%)	35.4	0.9	23.9	1.4	35.76
Mass fraction of Whey (%)	0.42	5.3	0.61	0.46	92.58
Mass fraction of starter culture (%)	3.5	1.04	3.1	0.7	87.5

Density of milk and whey is 1.032 g/cm^{3}and 1.024g/cm^3 respectively. Based on the process flow diagram, Material balance is made in order to specify completely all the equipments. The considered unit operations in the cheese making process are:

- Pasteurization (Heating and cooling)
- Bactofugation
- Sub Culture and rennet addition

- ❖ Curd making
- ❖ Cheddaring
- ❖ Salting and
- ❖ Pressing

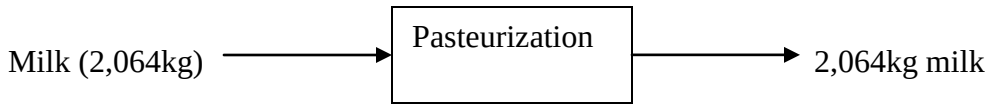
Pasteurization

Pasteurization of the milk is required prior to cheese-making to meet hygiene requirements by killing bacteria. Within the pasteurization process, the raw milk is heated to 71°C and held for 15 s, and then is cooled to repining temperature 30°C. The mass of bacteria in milk is so small that it was considered insignificant in this analysis.

$$m = \rho V$$

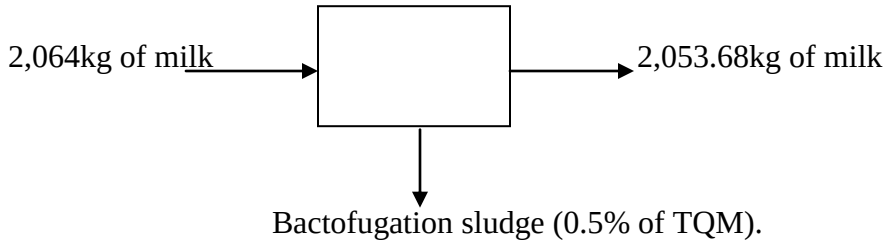
$$m = 1.032 g/ml * 2x10^{6} ml$$

$$m = 2064 kg$$



Bactofugation

Bactofugation line removes a portion of milk, leucocytes, dirt's as well as bacteria which may amount to 0.5% of the total quantity of milk (TQM).



Sub culture required

From commercial cheese formulation 0.015% of TQM sub culture was used.

In any process a steady state mass balance can be defined as:

The composition of starter culture is taken from literature and illustrated in table 5.1.

0.015% * 2,053kg = 0.3081kg

Total mass balance:

0.3081kg + 2,053.68kg = 2,053.99kg of sub culture and milk

Rennet Required

From laboratory result 0.0015% of TQM rennet was used with a composition of 14.3% rennet and 85.7% water. Hence the amount of rennet needed for 2,053.99kg of milk is calculated as follows:

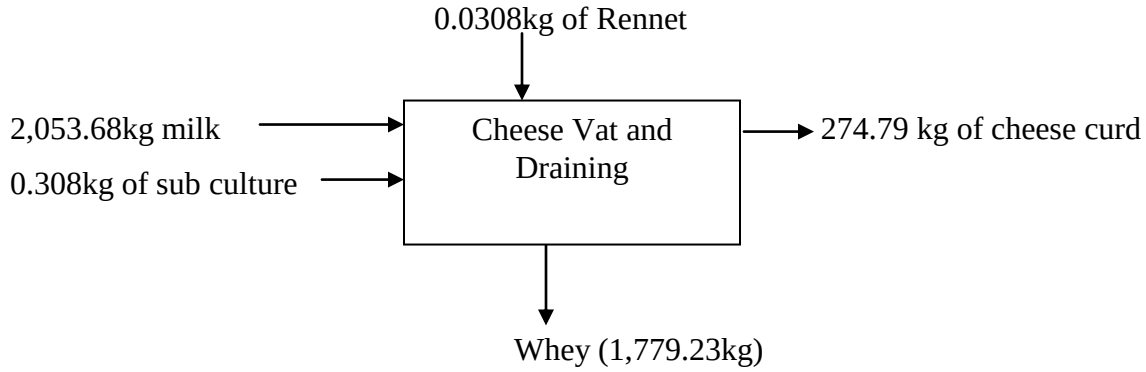
0.0015%*2,053.99kg = 0.0308kg

Total mass balance:

0.0308kg + 2,053.99kg = 2,054.02kg of rennet, sub culture and milk

Curd production

There are three streams flowing into the process and two streams coming from the process. Cheese milk from the bactofugation process is fed to a cheese vat. Starter culture and rennet enzyme are added to the cheese milk. Within the vat, the milk is coagulated by the action of the rennet and then the coagulum is cut and heated to form the curds and whey. The curds and whey are then separated by draining belt. The end of curd production is defined as the end of the curd drainage just before cheddaring process.



Total material balance:

2,053.68kg of milk + 0.308kg sub culture + 0.0308kg Rennet = Cheese (C) + Whey (W)

2,054.02 kg= C+W…… eq (1)

Where: C is cheese and W is whey in kg

Component mass balance

Composition of Whey is taken from literature and shown in Table 5.1

Fat Balance:

2,053.68kg * 5.1% + 0.308 kg * 3.5% = W * 0.42% + C * 35.4%

104.74kg + 0.0108kg = 0.0042W + 0.354C

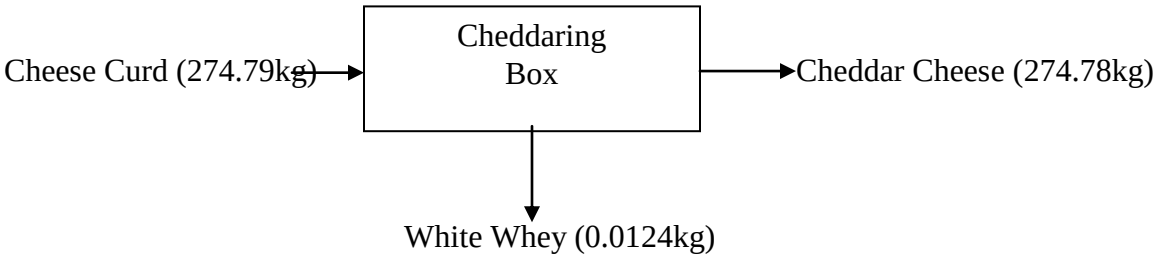
104.75kg = 0.0042W + 0.354C……. eq (2)

Equating the above two equations simultaneously, the value of C and W will be calculated as follows:

C= 274.79 kg of cheese

W= 1,779.23 kg of whey

Cheddaring



Total material balance

Cheese Curd = W + C

274.79kg = W + C.....eq (3)

Component Material Balance

Fat Balance:

274.79kg kg * 35.4% = W * 0.42% + C * 35.4%

97.28 kg = 0.0042W + 0.354C……. eq (4)

Equating eq (3) and eq (4) simultaneously, the value of C and W will be calculated as follows:

C= 274.78 kg of cheese

W= 0.0124 kg of whey

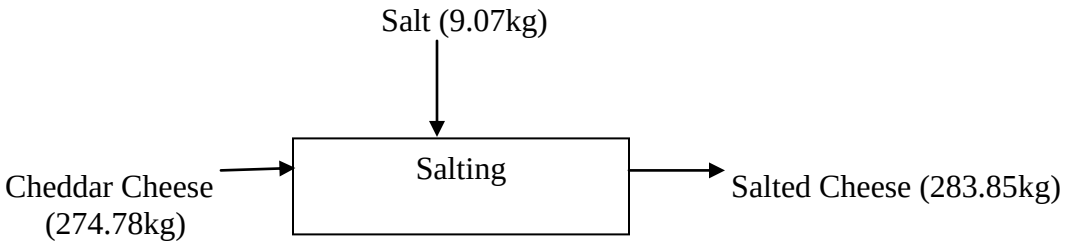
Salting

In the process of cheddar cheese manufacturing, 3.3kg of salt is needed for 100kg of cheese (Walstra, 2006). Calculating the amount of salt needed can be calculated as follow:

3.3kg salt = 100kg of cheese

? = 274.78 kg of cheese

Mass of salt needed for 274.78kg of cheese is 9.07kg



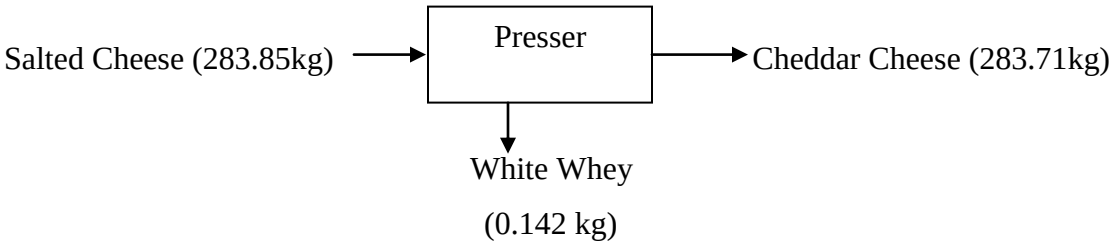
Total material balance:

Cheddar cheese + salt = Salted Cheese

274.78 kg+ 9.07kg = 283.85kg kg

Pressing

During pressing 0.05% of whey was removed.

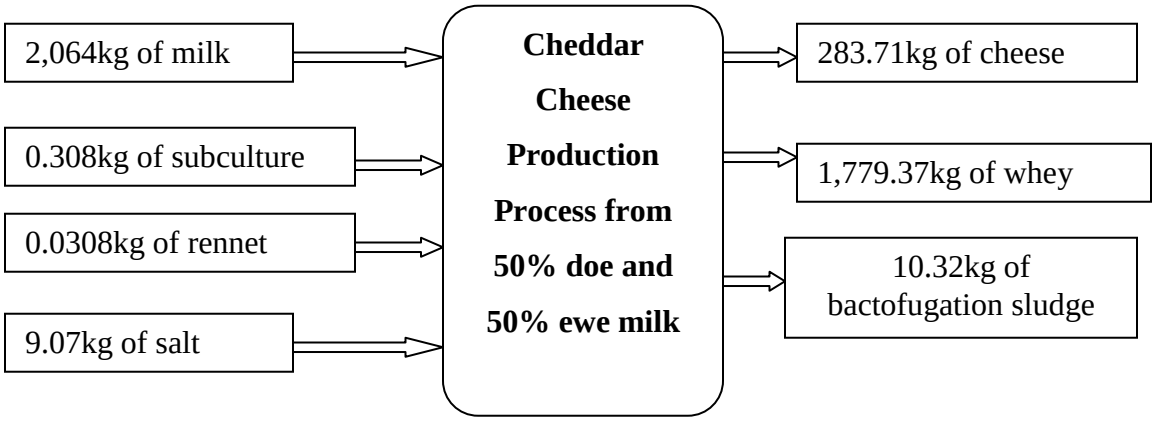


The final salted and pressed cheese has components illustrated in table 5.2

Table 5.2 Mass fraction of the final cheddar cheese

Component	Fat	Protein	Lactose	Ash	Salt	Water
Typical mass fraction (%) of cheese	35.4	23.9	0.9	1.4	1.9	35.76

Over all material Balance

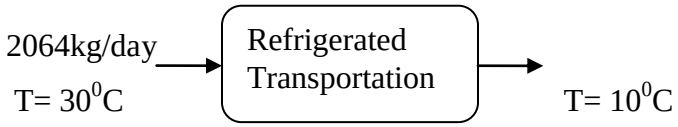


5.1.2 Energy Balance

In general, energy use in cheese making processing is associated with the above unit operations used for material balance. 2000liters of milk will be processed each day and 600,000liters of milk per year using 300 working days per year so energy for each unit operations will be calculated as follows:

Energy Balance on Refrigerated transportation

The milk temperature at the collection centre assumed to be 30^0C and with in the refrigerated truck the temperature maintained at 10^0C



Mean temperature = (30 +10)/2 = 20 ^{0}C

The specific heat capacity of milk at 20^0C can be calculated from the relation ship of specific heat capacity and milk composition as follows

$Cp=\sum (C_{pi}\ m_i)$

Where C_{pi} = specific heat of component i

m_i = mass fraction of component i

Specific heat of the component at the temperature of 20^0C

Protein $C_p = 2.0082 + 1.2089 * 10^{-3} T – 1.3129 *10^{-6} T^2$

$C_p = 2.0082 + 1.2089 * 10^{-3} (20\ ^0C) – 1.3129 *10^{-6} (20\ ^0C)^2$

C_p= 2.03 KJ/kg ^{0}C

Lactose $C_p = 1.54884 + 1.9625* 10^{-3}T – 5.9399*10^{-6}T^2$

C_p = 1.586 KJ/kg ^{0}C

Fat $C_p =1.9842 + 1.4733*10^{-3}T- 4.8008 * 10^{-6}T^2$

C_p = 2.012 KJ/kg ^{0}C

Ash $C_p = 1.0926 + 1.8896*10^{-3}T- 3.6817 * 10^{-6}T^2$

C_p = 1.129 KJ/kg^{0}C

Water $C_p = 4.1762 – 9.0864 * 10^{-5}T + 5.4731*10^{-6} T^2$

C_p = 4.177 KJ/kg^{0}C

The mass fraction of components in the raw milk are, fat 5.1 %, protein 4.13%, lactose 4.82%, ash 0.95% and water 86.3%.

$C_p=\sum (C_{pi}\, m_i)$

C_p = 2.03 KJ/kg ^{0}C*(0.0413) + 1.586 KJ/kg ^{0}C*(0.0482) + 2.012 KJ/kg ^{0}C*(0.051) + 1.129 KJ/kg^{0}C*(0.0095) + 4.177 KJ/kg^{0}C*(0.863)

C_p = 3.777 KJ/kg^{0}C

There fore $Q= mC_p(T_2 – T_1)$

Q = 2064kg * 3.777 KJ/kg ^{0}C * (10- 30)^{0}C

Q_1 = - 155,915.56kJ (negative sign indicates cooling process)

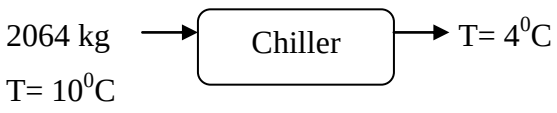
Assume the raw milk will be stored for 1hours before processing (3600seconds)

$P = Q/t$

P_1 = 43.31kw

Energy balance on the chiller

The milk after reception has to be chilled to 4^{0}C immediately to inhibit the bacterial growth before processing starts.



Mean temperature = (10 +4) /2 = 7^{0}C

C_p at mean temperature 7^{0}C

Protein $C_p = 2.0082 + 1.2089 * 10^{-3} T – 1.3129 *10^{-6} T^2$

$C_p = 2.0082 + 1.2089 * 10^{-3} (7^0C) – 1.3129 *10^{-6} (7^0C)^2$

C_p= 2.016 KJ/kg ^{0}C

Lactose $C_p = 1.54884 + 1.9625* 10^{-3}T – 5.9399*10^{-6}T^2$

C_p = 1.563 KJ/kg ^{0}C

Fat $C_p =1.9842 + 1.4733*10^{-3}T- 4.8008 * 10^{-6}T^2$

C_p = 1.984 KJ/kg ^{0}C

Ash $C_p = 1.0926 + 1.8896*10^{-3}T- 3.6817 * 10^{-6}T^2$

C_p = 1.1058 KJ/kg^{0}C

Water $C_p = 4.1762 – 9.0864 * 10^{-5}T + 5.4731*10^{-6} T^2$

C_p = 4.175 KJ/kg^{0}C

The mass fraction of components in the raw milk are, fat 5.1 %, protein 4.13%, lactose 4.82%, ash 0.95% and water 86.3%.

$C_p=\sum (C_{pi}\, m_i)$

C_p = 2.016 KJ/kg ^{0}C*(0.0413) + 1.563 KJ/kg ^{0}C*(0.0482) + 1.984 KJ/kg ^{0}C*(0.051) + 1.1058 KJ/kg^{0}C*(0.0095) + 4.175 KJ/kg^{0}C*(0.863)

C_p = 3.87 KJ/kg^{0}C

Q= m C_p ($T_2 – T_1$)

Q= (2064kg) * 3.87 * (4-10)

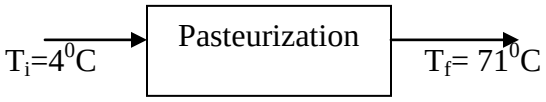
Q_2 = - 47,926.08 kJ

Assume the raw milk will be stored for 12hours before processing (432,000seconds)

$P = Q/t$

P_2 = 0.11094kw

Energy balance on pasteurization



To calculate C_P of milk at average temperature of 4^{0}C and 71^{0}C is at a temperature of 37.5^{0}C. Specific heat of milk at 37.5^{0}C can be calculated from the relation ship of Cp and milk composition with the following formula:

$C_p = \sum C_{pi}\, m_i$

Where C_{pi} = specific heat of component i

m_i = mass fraction of component i

Specific heat of the component at the temperature of 37.5^0C

For Fat:

$Cp = 1.9842 + 1.4733 \times 10^{-3}T - 4.8008 \times 10^{-6}T^2$

$C_p = 1.9842 + 1.4733 \times 10^{-3} (37.5^0C) - 4.8008 \times 10^{-6}(37.5^0C)^2$

$C_p = 2.0325$ kJ/ kg ^0C

For Lactose:

$C_p = 1.54884 + 1.9625 \times 10^{-3}T - 5.9399 \times 10^{-6}T^2$

$C_p = 1.54884 + 1.9625 \times 10^{-3}(37.5^0C) - 5.9399 \times 10^{-6}(37.5^0C)^2$

$C_p = 1.614$ kJ/ kg ^0C

For Protein:

$C_p = 2.0082 + 1.2089 \times 10^{-3} T - 1.3129 \times 10^{-6} T^2$

$C_p = 2.0082 + 1.2089 \times 10^{-3} (37.5^0C) - 1.3129 \times 10^{-6} (37.5^0C)^2$

$C_p = 2.0517$kJ/ kg ^0C

For Ash:

$C_p = 1.0926 + 1.8896 \times 10^{-3}T - 3.6817 \times 10^{-6}T^2$

$C_p = 1.0926 + 1.8896 \times 10^{-3}(37.5^0C) - 3.6817 \times 10^{-6}(37.5^0C)^2$

$C_p = 1.158$ kJ/ kg ^0C

For Water:

$C_p = 4.1762 - 9.0864 \times 10^{-5}T + 5.4731 \times 10^{-6} T^2$

$C_p = 4.1762 - 9.0864 \times 10^{-5}(37.5^0C) + 5.4731 \times 10^{-6}(37.5^0C)^2$

$C_p = 4.1805$ kJ/ kg ^0C

Therefore:

$$\mathbf{C_p = \sum C_{pi}\, m_i}$$

$C_p = 4.1805$ kJ/ kg ^0C (0.863) + 1.158 kJ/ kg ^0C (0.0095) + 2.0517kJ/ kg ^0C (0.0413)
+1.614 kJ/ kg ^0C (0.0482) + 2.0325 kJ/ kg ^0C (0.051)

$C_p = 3.8$ kJ/ kg ^0C

$Q = mC_p\Delta T$ where: m = 2064kg, Cp = 3.8kJ/ kg ^0C and

$$\Delta T = T_2 - T_1 = 4^0C - 71^0C = 67^0C$$

Q = 2064kg x 3.8kJ/ kg ^{0}C x 67^{0}C

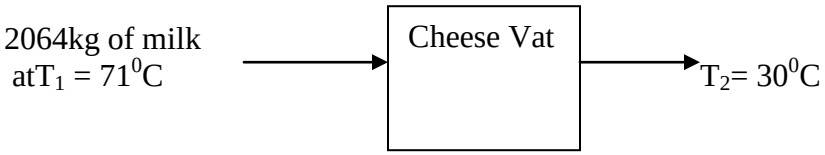
Q_3 = 525,494.4kJ and this much heat is needed for 15 seconds.

$P = Q/t$

P_3 = 35,032.96 kw

Energy Balance on Cheese Vat

C_p at average temperature of 50.5^{0}C is equal to: **3.83kJ/ kg^{0}C**



Q = $mC_p\Delta T$ where: m = 2064kg, Cp = 3.83kJ/ kg ^{0}C and

$\Delta T = T_2 - T_1 = 30^0C - 71^0C = -41^0C$

Q = 2064kg x 3.83kJ/ kg ^{0}C x 41^{0}C

Q_4 = 324,109.92 kJ and this much heat is needed for 9900 seconds (2.45 hr)

$P = Q/t$

P_4= 32.74kw

Total quantity of heat need for the process is:

Q = 155,915.56kJ + 47,926.08kJ + 525,494.4kJ + 324,109.92kJ

Q = 1,053,445.96kJ heat needed for cheese making process

Total power needed for the process is:

P= 43.31kw +0.11094kw +35,032.96 kw+32.74kw

P_T = 35,109.1209kw daily power needed for cheese making process

5.2 Economic Feasibility Study of the Thesis

As the thesis is new for our country, the start up should be in small scale so let us consider the daily input of 2000liters of 50% doe and 50% ewe milk mix ratio.

Capacity = 600,000 lit/year which is 619,200kg/ year.

Plant working days = 300 days/year

Working time = 24 hrs/day with two shift

The amount of total product per year can be taken from material balance result so that 2000liters of milk can produce 283.71kg of cheddar cheese each day.

m =85,110kg of cheese per year

- The amount of 50% doe and 50% ewe milk needed is **619,200 kg/year**
- The amount of rennet needed for cheese production **9.24kg/year**
- The amount of sub culture needed is **92.4kg/year**
- The amount of Salt needed is **2,721kg/year**
- The amount of whey produced per year is **533,811kg/year**
- Assume the product will be packed with vacuum packaging materials using wax whose capacity is 300 kg/day.

5.2.1 Techno - economic Analysis

- **Machinery and Equipment**

The following presents a summary of cost, taken form Ullmer's Dairy Equipment, Inc for mini dairy plant.

Table 5.3 Machinery and equipment requirements for Cheese making process

Item	Capacity (l/d)	Unit price, Birr	Total Price, birr
Cheese Vat and Agitator	2000	180000.00	180,000.00
Accessories, including paddles, forkes, knives	2000	38400.00	38,400.00
Press single row reconditioned	2000	26400.00	26,400.00
Cheese Hoops, 10 x 40lb (used) + 20 x 20lb (new) $2,500 $5,500	2000	30000.00	30,000.00
4 – 4000 liters refrigerated storage tank	3500	30000.00	30,000.00
1 – Westfalia raw milk cream/whey separator	2000	144000.00	144,000.00
Whey & Cream holding tanks	2000	18000.00	18,000.00
Boiler w/ feedwater pump – used	30 hp	90000.00	90,000.00
Single/Double vacuum packaging chamber	2000	36000.00	36,000.00
Batch Pasteurizer	2000	168000.00	168,000.00
Milk reception tank	2000	26,000	26,000.00
Standardization tank	2000	26,000	26,000.00
Cost of identified required equipment:			812,800.00
Additional miscellaneous equipment (15%)			121,920.00
Total equipment cost			**934,720.00**

❖ **Total capital investment cost estimation**

Table 5.4 Fixed capital cost estimation for cheese making plant

Item		Description / factor	Total Cost, birr
I. Direct Costs	A. a. Equipment		934,720.00
	b. Installation	0.47 x 934,720.00	439,318.40
	c. Instrumentation	0.18 x 934,720.00	168,249.60
	d. Piping	0.66 x 934,720.00	616,915.20
	e. Electrical	0.11 x 934,720.00	102,819.20
	B. Building + auxiliary	0.70 x 934,720.00	654,304.00
	C. Service facilities	0.70 x 934,720.00	654,304.00
	D. Land	0.06 x 934,720.00	56,083.20
	Total direct cost (sum of the above)		**3,626,713.40**
II. Indirect Costs	A. Engineering& supervision	0.1 x 3,626,713.40	362,671.30
	B. Construction +contractor fee	0.1 x 3,626,713.40	362,671.30
	C. Contingency	0.1 x 3,626,713.40	362,671.30
	Total indirect cost sum of the above three		**1,088,014.00**
III. Fixed capital investment (Direct +Indirect cost)			**4,714,727.40**
IV. Working capital		0.15 x 4,714,727.40	**707,209.00**
V. Total capital investment (Fixed capital investment + Working Capital)			**5,421,936.60**

❖ **Raw material cost**

Table 5.5 Raw material costs for cheese making plant

Item	Quantity Per year (kg)	Unit price, Birr	Total price, birr
Raw milk	619,200.00	10birr/ kg	6,192,000.00
Starter culture LAB	92.4	900birr/ 87 kg	955.86
Rennet	9.24	204 birr/ 19 kg	99.21
Salt	2,721.00kg	3.00 birr/1kg	8,163.00
Total			**6,201,218.07**

- **Cost of utilities**

Table 5.6 Cost of utilities for cheese making plant

Item	**Quantity per annum**	**Unit price**	**Total price/annual**
Electric Power	35,109.12 kw	0.90birr/kw	31,598.21
Cleaning chemicals	600kg	10birr/kg	6,000.00
Water	425,550 liters of water (5liter/kg cheese)	0.005	2,127.75
Packaging materials	333,048 packs	2birr/ pack	666,096.00
		Total	**705,821.96**

- **Product Sale**

Table 5.7 Sales of product

Product to be sold	Quantity of product per annual	Unit price	Total/annual
Cheese	85,110.00 kg	200 birr/kg	17,022,000.00
Whey	533,811.00kg	0.20 birr/kg	106,762.20
Total sale			**17,128,762.20**

❖ **Total product cost Estimation**

Table 5.8 Estimation of total product cost of cheese making plant

Item		Description/factor	Total cost, birr
I. Manufacturing cost	A. Direct production cost		
	Total product cost (TPC)	Total fixed charge/0. 15	3,960,371.33
	a. Raw material	Calculated	6,201,218.07
	b. Utilities	"	705,821.96
	c. Operating labor (OL)	0.1x TPC	396,037.33
	d. Supervisory	0.1x OL	39,603.70
	e. Maintenance	0.05 x FCI	235,736.37
	f. Lab charges	0.12 x OL	47,524.00
	Total of A		**11,586,312.76**
	B. Fixed Charges		
	a. Depreciation	0.1 x FCI	471,472.74
	b. Local taxes	0.02 x FCI	94,294.60
	c. Insurance	0.006 x FCI	28,288.36
	Total of B		**594,055.70**
	C. Plant overheads	0.1 x TPC	**396,037.33**
	Total manufacturing cost (Total of A + B + C)		**12,576,405.79**
II. General Expenses	a. Administrative cost	0.05 x TPC	198,018.57
	b. Distribution	0.1 x TPC	396,037.33
	c. Research &development	0.05 x TPC	198,018.57
	d. Interest	0.05 x TPC	198,018.57
	Total general expenses		**990,093.00**
III. Total Product Cost (Total manufacturing costs + Total general expenses)			**13,566,498.79**

From the above data the following characteristics can be calculated as follows:

5.2.2 Economic Evaluation

- **Return on Investment (ROI)**

Total income = Total annual sale

Gross Annual earning = Total Income - Total product cost

= 17,128,762.20 – 13,566,498.79

Gross Annual earning = 3,562,263.41 Birr

Net Annual Earning = Gross Earning – Tax

N.B Assume income tax to be 35%

Net Annual Earning = = 3,562,263.41 **–** (0.35 x 3,562,263.41**)**

Net Annual Earning = 2,315,471.22Birr

Cash Flow

The cash flow for each year is listed below assuming the plant to operate at 85% capacity at first year, 90 % at the 2nd year, 95% at the 3rd year and 100% for the next 7 years.

Table 5.9 Cash flow rates for ten years

Year	**Cash flow**
1st	1,968,150.537
2nd	2,083,924.098
3rd	2,199,697.659
7th up to 10th	7 (2,315,471.22) = 16,208,298.54

Cumulative cash flow for 10 years (Total profit) = **22,460,070.83Birr.**

The average net profit per year = **2,246,007.83Birr.**

TCI = Fixed capital + working capital = **5,421,936.40 Birr**

If the plant will depreciate over 5 years,

Depreciation per year = 471,472.74 / 5 = 94,294.548 Birr

$$ROI = \frac{(\text{Total profit} - \text{Total depreciation})\ (100\%)}{(\text{Total capital} \times \text{year})}$$

$$= \frac{(22{,}460{,}070.83 - 471{,}472.74)\ (100\%)}{5{,}421{,}936.60 \times 10} = 40.56\%$$

ROI = 40.56%

❖ **Pay Back Period (PBP)**

$$PBP = \frac{\text{Total fixed capital}}{\text{Average annual profit}} = \frac{4{,}714{,}727.40}{2{,}246{,}007.83} = 2.10 \text{ years}$$

PBP = 2.10 years

❖ **Break-even analysis**

The break-even analysis is the point at which sales revenues equal the costs of products sold (profit equals zero). When sales are below this point, the plant is making a loss, and at the point where revenues equal costs, the plant is breaking even and can be calculated as:

$$BEP = \frac{TFC}{(Sup - Vcup)} = \frac{TPC - DPC}{(Sup - Vcup)}$$

Where: BEP = Break-even point

Vcup = Variable costs per unit of production

Sup = Selling price per unit of production

TPC = Total production cost

DPC = Direct production cost

$$Vcup = \frac{Total\ \ production\ \cos t}{Amount\ of\ \ cheese\ \ produced}$$

$$= \frac{13{,}566{,}498.79 birr/year}{85{,}110.00\, kg/year} = 159.40\, birr/kg$$

$$BEP = \frac{TFC}{Sup - Vcup}$$

$$= \frac{4{,}714{,}727.40\, birr/year}{200\ birr/kg - 159.40\ birr/kg} = 116{,}126 kg/year$$

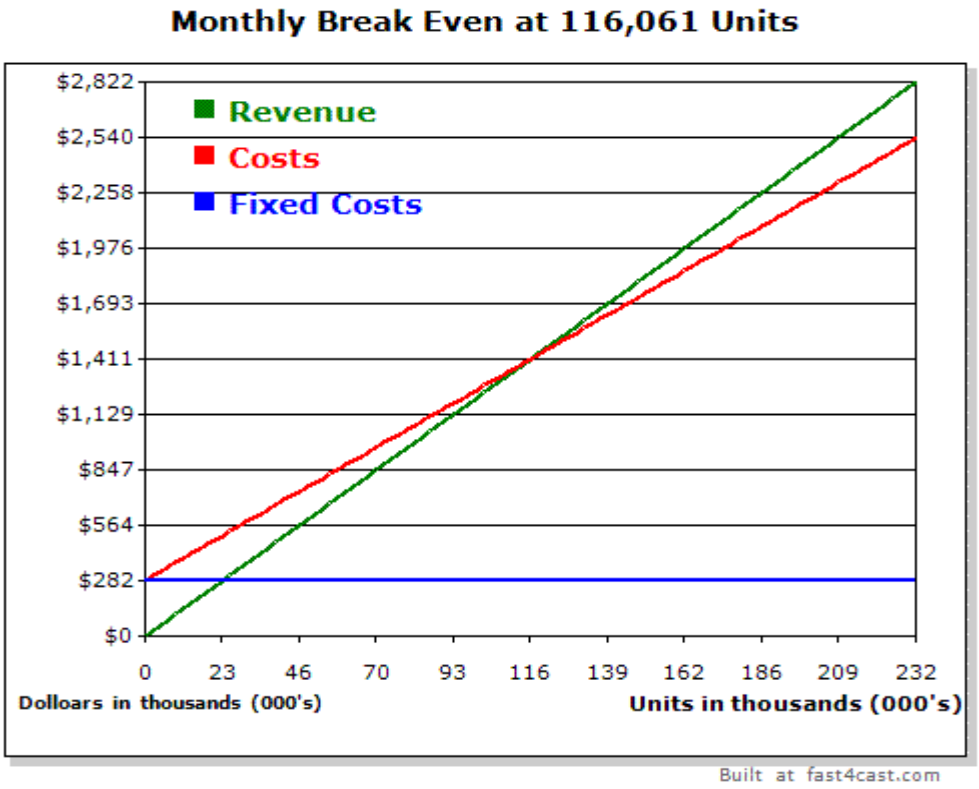


Fig 5.1 Break even conditions of the plant

5.2.3 Plant location and production program

The plant is planned to be at Awash 7 Kilo which can centralize Afar, Somalia and Oromiya regions. These region people are consumers of doe, ewe and camel milk. The selected location is best place in order to get raw material and market. The production program is to process 600,000 liters of milk per year and from this amount of milk 85,110 kg of cheese and 533,811liters of whey will be produced.

5.2.4 Summary on Economic Evaluation

Cheddar cheese processing plant form doe and ewe milk is planned to be in a very small scale and the economic evaluation show that total capital investment cost and the production cost are 5,421,936.60 and 13**,**566**,**498**.**79 respectively. The plant will create employment opportunities for 37 persons. The project is financially feasible with Return on Investment (ROI) of 40.56% and a payback period of 2.10 years. The plant has a capacity of production 85,110 kg of cheese and 533,811liters of whey from 600,000 liters of milk annually.

CHAPTER SIX

6. Conclusions and Recommendations

6.1 Conclusions

Doe and Ewe milk Cheese can provide a profitable alternative to cow milk products owing to their specific taste, texture, their natural and healthy image. This study strengthens the position of doe and ewe milk cheese as good suppliers of protein, energy, fat, minerals and vitamins.

In this thesis it was possible to produce cheddar and cottage cheese from doe, ewe and mixture of these milks following standard procedure for cheddar and cottage cheese processing technology. The pH change during cheddar cheese making was studied. Three main stage of cheddar cheese making was considered for pH analysis. These stages were ripening, cooking and cheddaring. During these stages, the decrease in pH was most rapid in 100% doe milk and slowest in that of 100% ewe milk.

Proximate, microbiological, physico- chemical, sensory analysis and yield of Cheddar cheese was done to compare the quality of cheddar cheese with control sample (100% doe milk cheese) and among each others.

From Proximate analysis; cheddar cheese made from 100% doe milk had the lowest moisture content and highest fat content of all the cheeses. There was a decrease in fat content of cheese with the composition of ewe milk mixed in each milk samples and the lowest fat content was recorded for cheddar cheese made from 25% doe and 75% ewe milk. Protein, total solid and lactose content didn't create difference between cheeses.

From microbiological analysis results, all cheeses did not exceed the limit for human consumption. Depending on texture result 100% doe milk cheese was harder (0.65 N/g) than the other mix ratio cheeses and this can be justified due to higher fat content.

Addition of doe milk to ewe milk had an effect on the yield of cheddar and cottage cheese compared to cheeses made from whole doe or ewe milk. The experimental results revealed that cheese yield differed significantly from different milk ratio.

The mean yield of cheeses was 0.66kg and 0.88kg for 100% doe milk and 100% ewe milk for cheddar cheese and 0.33 and 0.45 for cottage cheese, respectively. Increase in the percentage of ewe milk in the mixture for production of cheese increase cheese yield. This is because of higher total solid content of ewe milk than doe milk.

Despite the differences in composition and texture values, all cheeses received high organoleptiec scores. The use of ewe milk in any proportion with doe milk in the production of Cheddar cheese has no significantly unfavorable influence on cheese quality but has positive impact in the overall acceptability and yield of cheese. Mixing of ewe milk with doe milk increase the quality of cheddar cheese compared with cheeses made from 100% ewe milk or doe milk. From over all analysis the best acceptable and quality cheese was obtained from mix ratio of 50% ewe and 50% doe milk.

From economical point of view, the project is feasible and the total capital investment cost and the production cost are 5,421,936.60 and 13,394,962.33 respectively. The return on investment (ROI) is 35.21% with a payback period of 2.41 years. The plant will be located at pastoral and agro pastoral areas of Afar, Somalia and Oromiya regions (Awash 7 kilo).

Therefore it can be concluded that the development of ewe and doe milk cheese making technology is functional not only for the investors but also for the development of the country. Doe and ewe milk cheese can be a good source of nutritious food to alleviate poverty through satisfaction of undernourished and chronically food unsecured people specifically at pastoral areas of Ethiopia.

6.2 Recommendations

The following recommendations are made based on a holistic view of the subject area:

- Doe and Ewe raised by pastoralists in our country are generally low-producing in terms of milk but are well-adapted to the climatic conditions and are relatively tolerant of local diseases. To alleviate this problem cross breeds, management practice and feeding regime should be improved.

- There is a lack of information concerning the nutritional quality of doe and ewe cheese in our country, so advertisements has to be done to change the food habit of people. The current consumers of cheddar cheese from doe and ewe milk are foreigners and Afar, Somalia and part of Oromiya region are not utilizing the resource appropriately.

- The total process time of cheese making is longer when comparing to cow milk cheese processing; this can bring negative economical impact on over all process. Therefore the process parameters should be optimized for better production.

- There should be an effort to create marketing systems in our country in order to introduce the new product. In addition to this milk handling, transportation and storage facilities should be improved to attract investors in this area.

- There is also a growing of interest in Doe and Ewe milk cheeses world-wide. The present favorable situation will have to be consolidated in order to exploit consumer behavior and all potential marketing opportunities to other countries should be considered.

- Doe and Ewe milk production should get adequate emphasis and considered in the strategies to develop the rural areas and agro-food located systems.

- Further researches are required for whey utilization during cheddar cheese processing.

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Annex 1

Determination of Aerobic Bacteria Plate Counts (APC) in food

Method principle

The aerobic colony count estimates the number of viable aerobic bacteria per gm or ml of a product. A portion of the diluted sample mixed with a specified agar medium and incubated under specific temperature for 48 hr. It is assumed that each viable aerobic bacterium will multiply under these conditions and give raise to colonies.

Terms

Mesophillic bacteria: an organism whose optimum growth lies within a range generally accepted as 20-45^{0}C

Psychrophilic bacteria: an organism which grows optimally at or below 15 ^{0}C, which has an upper limit for growth at 20 ^{0}C , and which has a lower limit of 0 ^{0}C or lower.

Termophilic bacterial: an organism whose optimum growth temperature is >45 ^{0}C

Responsibilities All trained stuff with adequate experience.

Positive Control Reference material with known aerobic plate count.

Negative Control check sterility of PCA medium and diluents used by pouring control plates.

Equipment to Calibrate
Incubator37^{0}C for Mesophillic bacteria
Incubator 55^{0}C for Termophilic bacterial
Refrigerator 2-8 ^{0}C for Psychrophilic bacteria
Autoclave
PH meter
Safety cabinet
Pipettes controllers
Colony counting device
Centrifuge optional, only for some food type
Stomacher optional, only for none liquid sample
Digital balance

Media PCA

REAGENT 2%sodium citrate (tempered to 45 ^{0}c) (for cheese sample only)

Diluents peptone water diluents (SOP 4.2.15)

Procedure:

1. Sample preparation

Transfer 10ml of liquid sample to 90ml of diluents or 25g of sample to 225 ml of diluents in a flask if shaker used or in sterile plastic bag if stomacher used to make 10^1 dilutions (the first dilution)

Mix well with shaker/stomacher

2. Dilutions

Mix the first dilution by shaking then pipette 1ml into a tube (labled10^2) containing 9 ml of normal saline. Mix carefully by aspirating 10 times with a pipette.

From the 10^2 dilution, transfer with the same pipette 1ml to the tube (labled10^3) containing 9ml of the diluent, Mix with a fresh pipette.

Repeat until the required numbers of dilutions are made.

3. Pour plating

Pipette 1ml of each serial dilution into each of the appropriately marked duplicate dishes.

Pour 15-20ml of the molten PCA kept at 45 ^{0}C into each Petri dish.

Mix it thoroughly and allow it to solidify.

4. Incubation.

Incubate the dishes, inverted, at 35 ^{0}C or for dairy products at 32^{0}C for 48 hr.
N.B: Avoid excessive humidity in the incubator, to reduce the tendency for spreader formation, but prevent excessive drying of the medium by controlling ventilation and air circulation. Agar in plates should not lose weight by more than 15% during 48 hours of incubation.

5. Counting the colonies.

Following incubation, count all colonies within the range of 30-300 colonies and record the results per dilution counted.

Sample preparation: weigh 10g of the sample in to a sterile 250ml Erlenmeyer flask; marked to indicate 100ml volume. Add sterile saline peptone to 100ml mark. Dissolve and shake thoroughly.

Dilution: 1:10, 1:100, 1:1000, etc

Dilution factor: 1 x 10^1, 1×10^2, 1×10^3 etc

Inoculation: Pipette 1ml of the food homogenate and of each dilution of the homogenate into each of the appropriately marked duplicate dishes followed by pour plating of PCA.

Incubation : Incubate the prepared dishes, inverted, at 35^0C for 48 hours, and for dairy products at 32^0 C for 48 ± 3 hrs.

Counting colonies: Following incubation, count all colonies on dishes containing 30-300 Colonies, including those of pinpoint size and recorded the results per dilution counted.

Verification: If there is growth on the negative control and /or no growth on the positive control the test should be repeated with the corrected media

Expression of results: express the result in cfu per g /ml (if a liquid sample)

Calculation formula: Use the best two consecutive dilutions, as n_1 and n_2 to calculate the results.

$$N = C/V\ (n_1 + 0.1n_2)\ d$$

Where C = is the sum of colonies on all plates counted
V = is the volume applied to each plate
n_1= is the number of plates counted at first dilution.
n_2= is the number of plates counted at second dilution,
d = is the dilution from which first count was obtained.
N= is the average plate count.

Round the result to two significant figures and express it as a number between 1.0and 9.9 multiplied by 10^x where X is the appropriate power of 10.

Example; 1:10 1:100 1:1000
150 20 3 (No of colonies in each dilution).

Calculations: The two consecutive dilution will be taken for calculation (1:10and 1:100 in this case).

Therefore; No of colonies at first dilution =150
No of colonies at second dilution =20
Volume added to each plate =1ml

$N= (150 +20)/1x [1+0.1(1)] 10^{-1}$
$= 1.5x10^{3}$/ml or gm. (Average plate count)

Annex 2

Determination of aerobic colony count for mould and yeast in food

Method principle

The aerobic colony count estimates the number of viable aerobic mould and yeast per g or ml of product. A portion of the food homogenate is mixed with a specified agar medium and incubated under specific conditions of time and temperature. It is assumed that each viable aerobic mould/ yeast will multiply under these conditions and give rise to a colony.

Responsibilities All trained stuff with adequate experience
Positive Control Any spp. of mold and yeast.
Negative Control check sterility of PDA medium and diluents used by pouring control plates and incubate at 37°c and 22 °C for 5-7 days.

Equipment to Calibrate

Incubator 37°C
Incubator22°C
Autoclave
pH-meter

Media PDA

Diluents peptone water

Procedure:

1. Preparation of food homogenate

Transfer 10ml of liquid sample to 90ml of diluents or 25g of sample to 225 ml of diluents in a flask if shaker used or in sterile plastic bag if stomacher used to make 10^1 dilution (the first dilution)

2. Dilution

2.1 Mix homogenate by shaking and pipette 1ml into a tube (labled10^2 containing 9ml of normal saline. Mix carefully by aspirating 10 times with a pipette
2.2 From the first dilution, transfer with the same pipette 1ml to 2^{nd} dilution tube containing 9ml of the Ns, Mix with a fresh pipette
2.3 Repeat using 3^{rd} or more until the required numbers of dilutions is made
2.4 shake all dilution carefully.

3. Pour plating

3.1 Pipette 1ml of the food homogenate and of each dilution of the homogenate into each of the appropriately marked duplicate dishes.
3.2 Pour into each petridish 15-20ml of the PDA.
3.3 Mix the sample dilution and agar medium thoroughly and uniformly, allow solidifying.

4. Incubation. Incubate the prepared dishes, inverted, at 37^0c and 22^0c for 5-7 days.

5. Counting the colonies. Following incubation, count all colonies on dishes containing 30-
300 colonies and recorded the results per dilution counted.

Verification If there is growth on the negative control or if there is no growth on the positive control the test should be repeated.

Expressions of results calculate the average count and multiply by the dilution. And express the result in cfu per g –ml (if a liquid sample)
the result at 37^0c reported as yeast and mold count at 37^0c
the result at 22^0c reported as yeast and mold count at 22^0c

Annex 3

Enumeration of Staphylococcus aureus

Method principle
Certain staphylococci produce enterotoxins which cause food poisoning. This ability to produce enterotoxins, with few exceptions, is limited to those strains that are coagulase positive, and /or produce a heat stable nuclease (TNase). This method determines the presence of *S. aureus* by plating known quantities of (dilutions of) food sample onto a selective agar. After incubation presumptive staphylococcal colonies are selected and

subjected to confirmatory tests from the results of these tests the number of *S. aureus* per g or ml of the food is calculated .The quantity that present may indicate a potential for the presence of enterotoxin , or they may also indicate a lack of adherence to good hygienic practices.

Responsibilities: All trained stuff with adequate experience
Positive Control: *S.aures*
Negative Control: *E.coli*
Equipment to Calibrate: Incubator 37°C
Autoclave
pH-meter
Media: Baird-parker agar and Mannitol salt agar
Reagent Human plasma or commercial rabbit plasma
Diluents: Normal saline (Ns)/peptone water

Sample preparation
Weigh 10g of the sample in to a sterile 250ml Erlenmeyer flask marked to indicate 100ml volume. Add sterile normal saline to 100ml mark. Dissolve and shake thoroughly.

Procedure (1): Using Baird-parker agar media
1. Preparation of food homogenate
Transfer 10g of sample with sterile spoon or other depending on the sample type in to a sterile250ml Erlenmeyer flask containing 90ml of normal saline.

2. Dilution
2.1 mix homogenate by shaking and pipette 1ml into a tube containing 9ml of normal slain. Mix carefully by aspirating 10 times with a pipette
2.2 From the first dilution, transfer with the same pipette 1ml to 2^{nd} dilution tube containing 9ml of the Ns, Mix with a fresh pipette
2.3 repeat using 3^{rd} or more until the required numbers of dilutions are made
2.4 shake all dilution carefully.

3. Pipette 0.25 ml of the material on the plates (two plates for each dilution) and spread with a sterile bent glass rod. The plates are incubated at 37^0c for 24- 48 hr.

4. select plates with 30-300 separate colonies which are black and shiny with narrow white margins and surrounded by the zones extending in the opaque medium .Mark the position of these colonies and re-incubate for 24-hrs. Count all colonies with the above appearance that developed in the second 24 hrs incubation and submit these for coagulase test. Then total the colonies which produced clear zones in both periods of incubations. Multiply by 4 and by the dilution factor to calculate the number of staphylococcus auras per ml of sample.

Procedure (2): Using Mannitol salt agar media
Inoculate 0.1ml of the sample into the surface of the medium. Incubate as above and count the typical colonies which form yellow zones and not those surrounded by red or purple zones .This give the number of suspected staphylococcus.

Dilution: 1:10, 1:100, 1:100, etc
Dilution factor : 1 x 10^1, 1×10^2, 1×10^3
Inoculation: spread with a sterile bent glass rod
Incubation: Incubate the prepared dishes, inverted, at 37^0c for 48 h

Counting colonies: following incubation, count all colonies on dishes containing 30-300 colonies and recorded the results per dilution counted.

Verification: If there is growth on the negative control or no growth on the positive control the test should be repeated

Expression of results: after calculate the average count and multiply by the dilution express the result in cfu per g /ml (if a liquid sample)

Annex 4

Pictures