CZECH UNIVERSITY OF LIFE SCIENCES

FACULTY OF ENGINEERING

DEPARTMENT OF TECHNOLOGICAL EQUIPMENT OF BUILDINGS

DIPLOMA THESIS

OPTIMIZATION OF PRODUCTION PROCESSES IN MILK INDUSTRY

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CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE
Department of Technological Equipment of Buildings
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DIPLOMA THESIS ASSIGNMENT

Buddhasiri Sujeewa

Thesis title
Optimization of production process in milk industry

Objectives of thesis
The aim of this diploma thesis is evaluation and optimization of complete production process in milk industry in farms and companies with different operating conditions. The starting point for addressing is the situation in dairy farms and milk processing in Sri Lanka. The study should result in proposal of applications suitable for use in developing countries, especially in hot climatic conditions.

Methodology
Based on the literature overview consider different conditions of production and evaluate suitable use and application of dairy farms technology in practical farming. The whole chain of milk production going from farmer to consumer should be studied mainly with the aim how to increase quantity and quality of milk. The attention should be paid to milk treatment, cooling and also to milk processing improvement, respecting the different farms and industry levels.

Outline of the structure
1. Introduction
2. Milk production and consumption in world statistics
3. Technology and equipment in traditional dairy farms
4. Technology and equipment in large scale farms
5. Milk processing and distribution in local traditional farms
6. Milk processing and distribution in progressive commercial industrial chains
7. Conclusions and recommendations for practical applications

The proposed extent of the thesis
50 to 60 pages of text

Keywords
Dairy farms; milking machines; milk cooling; milk processing

Recommended information sources

Bartali, H.: CIGR Handbook of Agricultural Engineering. Volume II. Animal Production and Aquacultural Engineering. ASAE, 1999, 359 p.
Bakker-Arkema, F.W.: CIGR Handbook of Agricultural Engineering. Volume IV. Agro Processing Engineering. ASAE, 1999, 527 p.
Gustavsson, J. et al. Global food losses and food waste (Extent, causes and prevention). FAO, 2011, 38 p.
FAO Statistical Year Books
Journals: Biosystems engineering; AMA – agricultural mechanization in Africa, Asia and Latin America

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Prague February 3. 2014

Declaration

This thesis is a presentation of my original research and project work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

The work was done under the guidance of Professor Pavel Kic, at the Faculty of Engineering, Czech University of Life Sciences.

Prague on 30th March 2015

……

Sujeewa Buddhasiri

Faculty of Engineering,

Czech University of Life Sciences.

Acknowledgement

I would like to express my deepest appreciation and thanks to all those who provided me the possibility to complete this project thesis. I would like to give my first gratitude to my parents for advising and guiding me at all the times.

I would like to express my special appreciation and thanks to my thesis supervisor Professor Pavel Kic (Ing., Ph.D., D.Sc.). I would like to thank you for encouraging my project works at all the time and your advice on both project works as well as on my career have been priceless.

I would also like to acknowledge with much appreciation the support of the staff of the University Farm in Ruda, for their assistance during the stay in there for industrial experience.

Abstract

Milk has been considered as nutrient food and beverage to the human body since the beginning of human civilization. In this project work, optimization the production processes in milk industry is mainly focused with 7 chapters. The first chapter describes the development of livestock industry with agriculture and the importance of milk as a nutrient food and beverage to the human body. Statistical data related to the milk processing industry in current world is mainly discussed in the second chapter. Afterwards the technological equipments and technologies used in traditional and modern farms including animal housing, feeding, milking methods, further processing of milk and usages of milk to other applications are discussed. Technical parameters for selection of milking parlor, milk cooling and milk storage are calculated in the Chapter 05. The conclusions of the observations and improvements to increase the efficiency are discussed in the last chapter. The recommendations for dairy farms in Sri Lanka are also discussed with new implementations in suitable areas.

Keywords

Dairy farms, milking machines, milk cooling, milk processing

Abstrakt

Mléko je považováno za výživnou potravinu a nápojpro lidské tělo od počátku lidské civilizace. Tato diplomová práce je zaměřena na optimalizaci výrobních procesů v mlékárenském odvětví a je rozdělena donásledujících sedmi kapitol.První kapitola popisuje vývoj živočišné produkce, zemědělství a význam mléka jako potraviny a nápojepro lidský organismus.Statistické údaje související se zpracováním mléka v současném světějsou uvedeny především v druhé kapitole. Poté jsou popsány technologie a technologická zařízenípoužívané v tradičních mléčných farmách, včetně ustájení zvířat, krmení, dojení, další zpracování mléka a jiné způsoby využití mléka.Technické parametry pro výběr dojírny, chlazení a uskladnění mléka včetně výpočtu základních parametrů jsou uvedeny v páté kapitole. Závěry z vlastní výzkumné činnosti zaměřené na rozvoj, zlepšení a zvýšení efektivnostimléčných farem na Srí Lance, včetně výběru a doporučení vhodných oblastí jsou popsány v poslední kapitole.

Klíčová slova

Mléčné farmy, dojicí stroje, chlazení mléka, zpracování mléka.

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1.Introduction

1.1 Civilization

From the beginning of the human civilization, people have 3 basic needs as food, housing and clothing. To fulfill these basic 3 needs people used many methods and techniques which were changed from time to time and geographical are to geographical area.

At the very beginning, people used hunting methods to fulfill their food requirement. After that people tended to maintain their own livestock and agricultural farms. These agricultural farms and livestock were very much useful for people in many ways to fulfill their food requirement throughout the year. Especially in the bad climatic conditions people were unable to travel to find food and hence their own agricultural farms and livestock were helpful to fulfill their food requirement.

1.2 Development of livestock facilities with agriculture

The main food source at the beginning of the human history was agriculture. Lots of techniques were used to increase the efficiency of the process of agriculture. Maintain a livestock is one of those techniques to create another source of food. By maintaining a livestock, farmers could fulfilled several tasks in their farms instead of the usage to fulfill their food requirement;

- Prepare the land for cultivation
- Take fertilizers and milk
- Usage for transportation of goods
- Clothing (Examples: Wool, Leather)

1.3 Importance of milk to the human body

Milk and dairy products contain many nutrients and provide a quick and easy way of supplying these nutrients to the diet within relatively few calories. The nutrients included in milk and their benefits are summarized in Table 1.

Nutrient	Benefits
Protein	For growth and repair
Calcium	For healthy bones and teeth
Phosphorous	For energy release
Magnesium	For muscle function
Vitamin B12	For production of healthy cells
Vitamin A	For good eyesight and immune function
Zinc	For immune function
Riboflavin	For healthy skin
Folate	For production of healthy cells
Vitamin C	For formation of healthy connective tissues
Iodine	For regulation of the body's rate of metabolism

Table 1: Nutritional contents of milk and their benefits

1.4 Further development of livestock and milk industry

1.4.1 Development of livestock industry

With development of many industries, livestock industry was also developed and still people try to develop the many areas of this industry. With development of livestock industry, it produced not only meat and milk, but also fiber, leather, labor, fertilizer, wool, draught…etc. The Table 2 illustrates the variation of usages of different kinds of animals.

The technologies which were introduced to the livestock industry are also important to be considered. There are many technological equipments were innovated from time to time depending on the problems and other factors (climate, food, water, storage and labor availability) faced by the farmers.

Animal / Type	Domestication Status	Wild Ancestor	Area of first captivity / Domestication	Current Commercial Uses
Alpaca	Domestic	Vicuna	Andes	Wool, meat
Banteng	Domestic	Banteng	South East Asia	Meat, milk, draught
Bison	Captive	N/A	North America	Meat, leather
Camel	Domestic	Wild Dromedary and Bractrian Camels	Asia	Mount, pack animal, meat, dairy, camel hair
Deer	Captive	N/A	United Kingdom	Meat, leather, antlers, antler velvet
Donkey	Domestic	African Wild Ass	Egypt	Mount, pack animal, draught, meat, dairy
Gayal	Domestic	Gaur	South East Asia	Meat, draught
Goat	Domestic	Wild goat	South West Asia	Dairy, meat, wool, leather, light draught
Horse	Domestic	Wild horse	Eurasian Steppes	Mount, draught, dairy, meat, pack animal
Sheep	Domestic	Asiatic mouflon sheep	South West Asia	Wool, dairy, leather, meat
Water buffalo	Domestic	Wild Asian water buffalo	South Asia	Mount, draught, meat, dairy
Yak	Domestic	Yak	Tibet, Nepal	Meat, dairy, wool, mount, pack animal, draught

Table 2: Domesticated animals and current commercial uses

1.4.2 Development of milk industry

Technological development in dairy farms and milk processing is considerable especially in the 19th century. There were many innovations in the new technological equipments in all the areas of milking process. The major innovation in milking process was the milking parlor.

Usage of milking parlor was caused to reduce the human involvement in milking process and farmers were able to pay their extra time to other activities in their farms.

1.5 Objective of the project

The main attention is given to the overall production process of milking in dairy farms and dairy manufacturing plants. The overall efficiency plays an important role in the production processes and depending on that overall efficiency, new machinery and technological equipment should be introduced to the existing system.

The measurement of time consumption is a key objective in the all unit processes hence it is used when the overall efficiency is calculated. In this project, time consumption in all the unit operations of milking parlor were measured to get deep understanding in the efficiency.

The total energy requirement is another factor to be considered in the unit processes. The total energy was calculated using several methods especially for cooling and storage of milk in dairy farms.

Finally, the areas which should have more attention to be given in order to increase the efficiency of overall process are identified. And also special attention is given to the identification of suitable dairy farm for Sri Lanka depending on its climatic conditions and socio economic environment.

2. Milk production and consumption in world statistics

2.1 Statistical data in milk production

In here, main attention is given to the statistical data of milk production in Sri Lanka, Czech Republic and the World. The main sources of information in statistics are central bank reports of related countries, publications published by nongovernmental organizations (Food and Agriculture Organization of the United Nations, International Farm Comparison Network) and other governmental publications by related countries.

2.1.1 Milk production in Sri Lanka

The main source of information for statistical data in milk production in Sri Lanka is the Central Bank Report [(1)] which is published in 2012.

The total production of milk in Sri Lanka is not sufficient to its demand. The Table 3 illustrates the current production capacities of milk in Sri Lanka.

Sub Sector	Unit	2011	2012
1. National Herd	No. (millions)	1.6	1.6
1) Neat Cattle		1.2	1.2
2) Buffalo		0.4	0.4
2. National Milk Production	Liters (millions)	258.3	299.3
1) Cow milk		203.5	237.6
2) Buffalo milk		54.8	61.6
3. Milk Products	Liters (millions)	21.4	29.3
4. Producer Price – Cow milk	Rs. / Liter	50.00	50.00
5. National Egg Production	No. (millions)	1185.3	1457.1
6. National Poultry Meat Production	Metric tons (thousands)	116.8	122.5

Table 3: Milk production in Sri Lanka

There are several actions and steps have been taken by the government of Sri Lanka to promote the effectiveness of the dairy sector to the national economy. The results of these steps can be summarized as in the Table 4.

Description	Unit	2011	2012	Effect
Total milk production includes cow and buffalo milk	Liters (millions)	258.3	299.3	+16 %
Milk collection in the formal sector	Liters (millions)	143.7	183.6	+28 %
Milk collection from farms under National Livestock Development Board	Liters (millions)	2.83	3.4	+20 %
Milk collection by Milco	Liters (millions)	52.3	68	+30%
Production of milk powder by Milco	kg (millions)	3.68	4.6	+25 %
Import of milk powder	kg (millions)	84.0	79.4	-5.5 %

Table 4: Improvements of dairy sector in Sri Lanka

2.1.2 Milk production in Czech Republic

Description	Unit	Year								
		1989	1993	1997	2000	2001	2002	2003	2004	2005
Dairy cows	’000	1248	830	702	615	483	477	459	433	439
Yield	Liter/cow. year	3982	3824	4366	5255	5762	5720	5764	5983	6062
Milk production	Million of liter	4893	3351	2703	2708	2783	2729	2646	2602	2661

Table 5: Milk production in Czech Republic

Source of information: Country pastures / Forage resource profiles – Czech Republic By Josef Kralovec [(2)]

The graphical interpretation of these data is illustrated in Figure 1 and fluctuations in the milk production and milk yield can be observed.

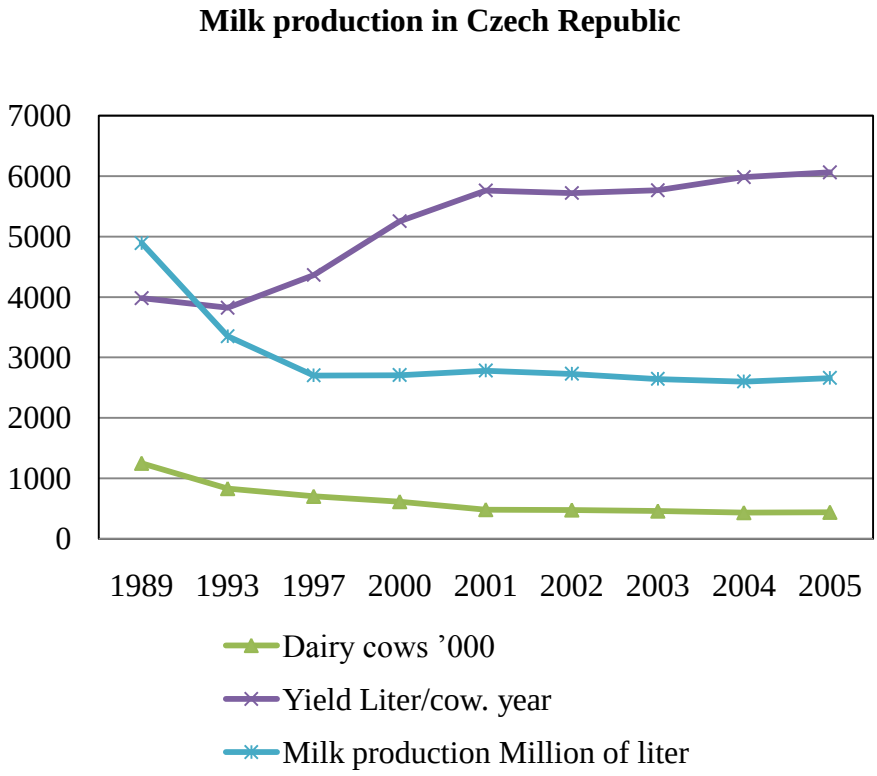

Figure 1: Milk production in Czech Republic

2.1.3 Milk production in the world

The main source of information for the milk production in the world was Annual Report 2012 [3] by Food and Agricultural Organization.

Sub Sector	2011 (metric tons)	2012 (metric tons)
Milk, whole fresh buffalo	95,674,354.60	97,417,134.60
Milk, whole fresh camel	2,916,993.00	2,785,382.00
Milk, whole fresh cow	612,773,765.02	625,753,801.38
Milk, whole fresh goat	17,695,426.90	17,846,118.00
Milk, whole fresh sheep	9,930,800.30	10,122,521.50
Milk, Total	738,991,339.82	753,924,957.48

Table 6: Milk production in world

Source of information: Annual Report 2012 by Food and Agricultural Organization (FAO)

2.2 Statistical data in milk consumption

The required amount of milk is a function of the population. Therefore required milk consumption is calculated using the population in respective country or the region.

2.2.1 Required milk consumption in Sri Lanka

Population of Sri Lanka = 20.264 million
Recommended dietary allowance = 100 ml/person per day
Total consumption per year = 739.64 million liters

2.2.2 Required milk consumption in the world

Population of world = 7.046 billion
Recommended dietary allowance = 100 ml/person per day
Total consumption per year = 257.179 billion liters

2.3 Statistical data in prices

2.3.1 Farmers' milk prices [4]

The most important factor for dairy farmers is selling price of milk in economic point of view. Milk prices change from country to country and range from US$ 15 to US$ 74 per 100 kg of ECM (Energy Corrected Milk). There are 5 categories of countries depending on the price of milk.

1) US$ 20: Argentina, Paraguay, New Zealand, Belarus, Ukraine, Uruguay, Pakistan, Uganda and Indonesia.
2) US$ 20 to 25: Uzbekistan, Brazil, Australia, Chile, Nigeria, Peru, India, Bolivia and Lithuania.
3) US$ 25 to 30: Vietnam, Bulgaria, Turkey, China, Russia, Kazakhstan, South Africa, Romania, Colombia, Poland, Kenya, Ecuador and a number of Central American countries.
4) US$ 30 to 40: United States of America, Venezuela, most EU countries, Czech Republic, Estonia, Hungary, Slovakia, Slovenia, Israel, Mexico, Mongolia, Iran, Morocco, Algeria, Myanmar, Ethiopia, Philippines, Cameroon, Tunisia, Thailand and Malaysia.

5) US$40: Iceland, Finland, Canada, Italy, Greece, Norway, Switzerland, Sudan, Saudi Arabia, Mozambique, Egypt, Japan, Taiwan and South Korea.

2.3.2 Milk : Feed Price Ratio

The milk : feed price ratio [5] as defined by IFCN (International Farm Comparison Network) as the milk price divided by the price of purchased feed. It indicates how much feed (in kilograms of concentrate) is required to buy with the sale proceeds from one kilogram of milk. The higher the ratio illustrates that the more economical and it is to use concentrates to feed the dairy cows. Currently IFCN regards the ratio as favorable for the use of concentrates when it is higher than 1.5, which is when high input and high yield dairy systems become profitable.

Countries which are producing cow milk can be categorized in to 3 main categories depending on the milk : feed price ratio.

1) High milk : feed price ratios (more than 2.5)

Highly favorable milk : feed price ratios of more than 2.5 are found in Greece, Kazakhstan, Canada, Egypt, Mongolia, Saudi Arabia, Sudan and the United States of America. In most cases, the cause of a high milk : feed price ratio is a very high milk price (up to US$ 30 per 100 kg) while in a few cases it is caused by feed prices significantly below the world market level.

2) Intermediate milk : feed price ratios (1.5 to 2.5)

Most countries of Europe and the Common wealth of Independent States (CIS) fall into this category, as well as Brazil, Ethiopia, Argentina, India, Japan, Ecuador, Republic of Korea, Mexico, Vietnam and Morocco.

3) Low milk : feed price ratios (less than 1.5)

Very unfavorable milk : feed price ratios (less than 1.0) can be observed in Guatemala, Indonesia, Cameroon, Nigeria and Uganda, whereas they are slightly better (1.0 to 1.5) in China, Ireland, Myanmar, Australia, New Zealand, Norway, Chile, Pakistan, South Africa, Switzerland, Peru, Thailand, Turkey and Uruguay. In most cases, the causes of unfavorable milk : feed price ratios are low milk prices (less than US$20 per 100 kg).

3. Technology and Equipment in Traditional Dairy Farms

There is a considerable difference can be observed in many activities and technologies used in dairy farms in history. In this chapter, technologies and equipment used in traditional dairy farms has been reviewed. And also the usages and applications of cow milk from history are discussed in this chapter.

3.1 Animal housing

Timber was used as the major construction material for animal housing. There are many advantages of using timber as construction material for animal housing.

3.1.1 Advantages of timber in animal housing

1) Renewable resource – Wood is constantly renewed by natural methods every 60 to 120 years.
2) Easy to work – Timber is the most easily worked of all structural materials. Because of that timber has remained a primary construction material for thousands of years in construction of all structural works.
3) Light material – Timber has low density compared to other building materials. The density of coniferous trees is approximately 500 kgm^{-3}, while the densities of concrete and steel are 2500 kgm^{-3} and 8000 kgm^{-3} respectively.
4) Strength – Timber has very good strength / weight ratio than other construction materials.
5) Withstand impact – Timber has good property in absorbing impacts.

3.1.2 Structures in timber

There are many structures were used in the construction of animal housing. The factors influencing the choice of structural system are,

- The farmer's intentions
    - Type of production
    - Size of production building
    - Technical installations
    - The site of building

- Financial solutions

➢ Codes, regulations and guidelines
  - Loads
  - Environmental aspects
  - Fire-risk considerations

➢ Choice of materials and building procedure
  - Durability
  - Price
  - Use of own timber
  - Own labor input
  - Possibilities for transport and erection

Figure 2 shows some of the structures used in animal housing.

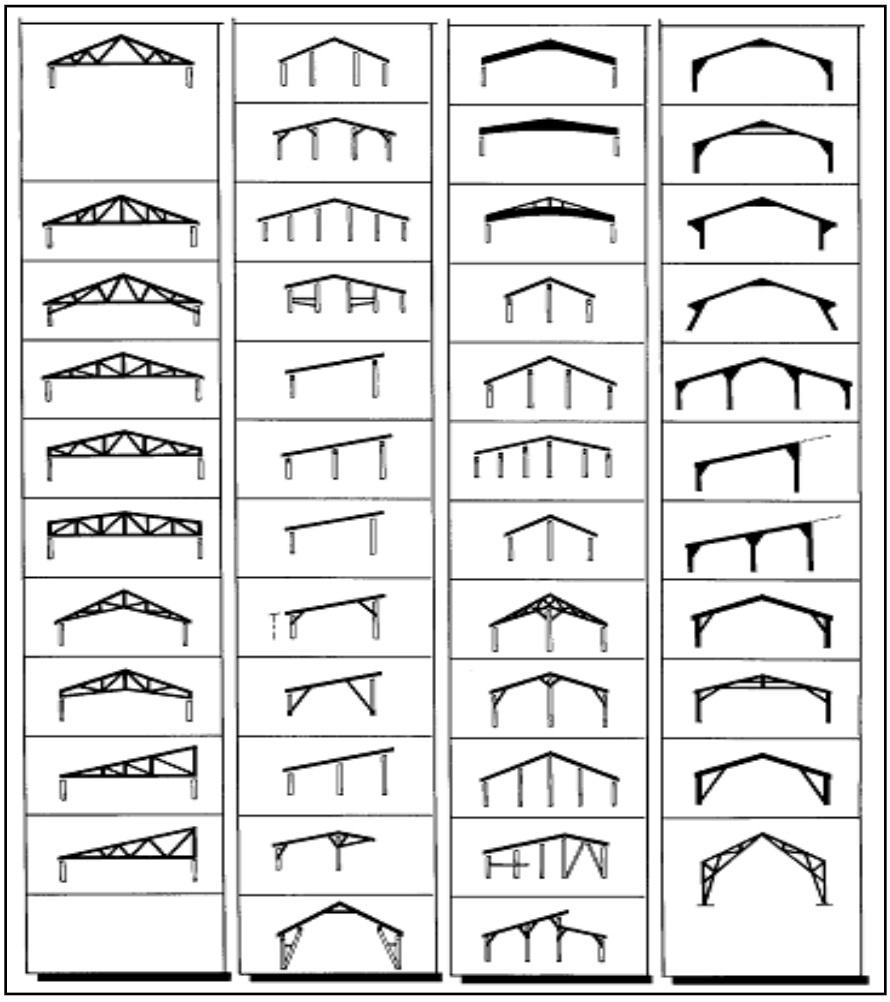

Figure 2: Structures used in animal housing

3.2 Feeding

Adult cattle spend about 5 hours per day in eating. In order to avoid competition, frustration, and aggression, there should be sufficient feeding places for all animals to feed at the same time. In traditional dairy farms, hay racks were mainly used to feed the animals.

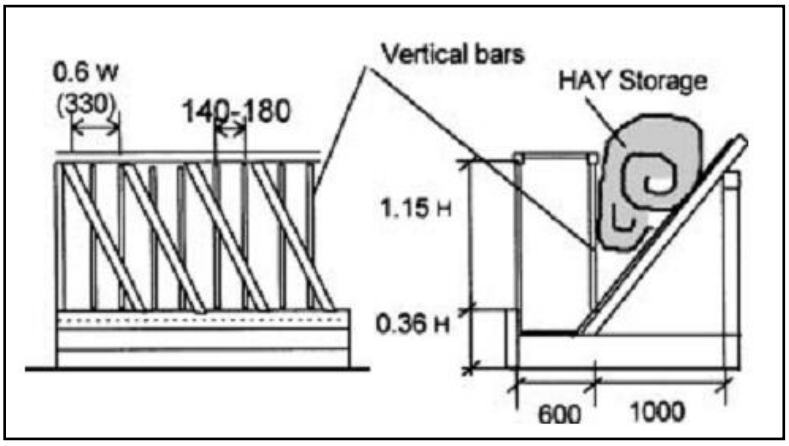

Figure 3: Hay racks for feeding

3.3 Milking process

At the very beginning in the milking of dairy cows, manual methods were used to get milk. The problems involved in hand milking were,

- Much time consumption for milking
- Maintaining the hygiene of milk
- Much labor involvement
- Problems in the manipulation of milk

By the development of technologies, there were several milking machines were introduced to milking process.

3.3.1 Milking tubes

The first successful milking machine was introduced as early as 1870. However they were not commonly used until several decades later.

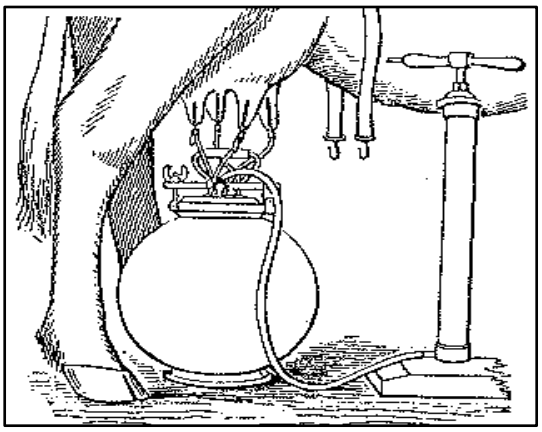

Figure 4: Milking tubes

Tubes were inserted into the cow's teats forcing them open for milk to flow. This was uncomfortable and injurious to the cow and often led to continuous dribbling and an increased risk of contamination of milk and udder.

3.3.2 Thistle vacuum milker

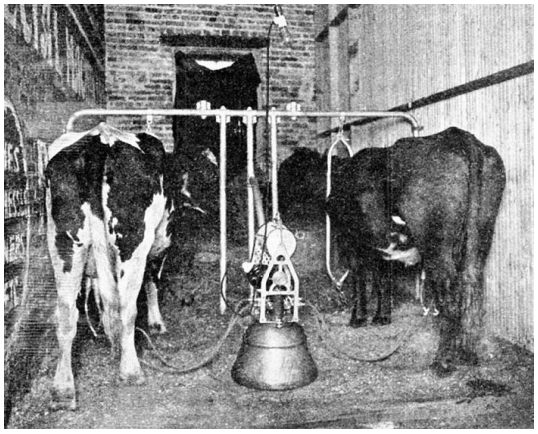

Figure 5: Thistle vacuum milker

This was firstly introduced in 1895. The pulsator was used to create an intermittent flow so that the teat would have time to refill and the vacuum action of the machine would not be damaging to the animal.

3.3.3 Surge milking machine

Figure 6: Surge milking machine

This was invented by Herbert McCornack in 1922. The surge milker was used a pulsator to imitate the action of pull movement like that of a calf. The biggest advantage in this machine was the ability to easily clean and sanitize the surge.

3.4 Further processing of milk

There are many usages and products of milk in many ways. Some of these processing methods are unique for regions in the world and some of processing methods are common for all over the world. In here, some of steps involved with these processing methods are discussed.

1) Curd or Dahi [(6)]

- Boil the milk – To ensure the milk does not spoil during the fermentation process.
- Keep the milk to become room temperature – If milk is very hot, milk gets coagulates and if milk is cold, curd will not set after fermentation properly, when culture is added.
- Add the curd culture – When culture is added to the milk, it should be warm. It is very important to dissolve the curd culture uniformly in the milk. Whisk very well with a spoon or a whisker.
- Keep the mixture stationary for 4 to 5 hours to set the curd

2) Yoghurt

In traditionally, yoghurt is made similar to curd, but currently there are some more ingredients are used such as sugar, gelatin, custard powder and flavors. Yoghurt making is much developed now and the processes involved in modern yoghurt manufacturing facility are discussed in Chapter 6.

3) Butter

- Separate the cream from milk by gravity – Just after milking, the milk was allowed to sit in pans or cans until the cream. Cream is floated to the top of the milk.
- Skim off the cream of milk – Cream of milk should be stored in a cool and dry place.
- Churn into butter – When several days' cream had accumulated, it was churned into butter.

4) Ghee

- Cook the butter in uncovered saucepan over a medium heat.
- Stir it continuously.
- Keep it in a steady simmer until it turns golden in colour with no white froth on the surface.
- Leave it to cool.
- Sieve the liquid using a stainless steel mesh or a muslin cloth.

5) Milk toffee

- Add condensed milk and sugar into a large saucepan on a stove.
- Keep stirring while adding cashew nuts and several essences.
- When the mixture get thick, pour into a flat tray and keep it until hardened.

6) Paneer

- Heat the milk and bring to boiling temperature.
- Add the lemon juice, vinegar or curd.
- Stir the milk when it is curdling.
- Drain the curdled milk by using a muslin or cotton cloth.
- Make heavy weight on the collected curdled milk for 30 – 40 minutes.

3.5 Usages of milk and its products

Milk is used in various applications since in long history. Ayurveda is one of major area which milk is used especially in South Asian countries. There are several treatment methods in Ayurveda [7] that milk is used.

1) Milk with herbs

When some certain herbs with pungent and hot properties are used in the treatments for a person with less strength, those herbs are processed with cow milk. This serves 3 purposes,

- The herbal remedy gets extra nutritional quality of milk.
- The pungency and the strength of the herb are lowered. Therefore the herbal formula is suitable for patient with less strength.
- Milk acts as fat and water soluble media for the active principles in the herb.
  Example: Garlic processed with milk, used in digestion problems

2) Milk in ayurvedic oils

In processing many oils which desired to have nourishing and rejuvenating effects, milk is added and processed along with oil.

This is especially beneficial in ayurveda oils are,

- Used for massage against degenerative diseases like osteo arthritis.
- Used to calm burning sensation.
- Used to heal nerve irritation and nerve pain.
- Used to nourish and strengthen muscles and ligaments.
- Example: Ksheerabala Taila

3) Shirodhara with cow milk

Shirodhara is a procedure which continuous stream of liquid is directed uniformly over the forehead region of human body. Milk is used in cases of headaches and dizziness in the Shirodhara.

4) Cow milk in Basti

Basti is a Panchakarma procedure and it is also a type of enema. Milk processed with herbs is used for Basti in many acid peptic disorders in ayurveda.

5) Cow milk for gargling

Cow milk is also used to relieve burning sensation and to relieve oral ulcers in ayurvedic treatments.

3.6 Waste / slurry transportation

In traditional dairy farms, more conventional methods were used to transport the slurry and the solid waste. Slurry is mainly transported using gravity in reduced concentrations by adding extra water. The drainage system should have proper angle to transport the slurry in effective manner.

There were not specific treatment methods for the slurry before it releases to the environment, except basic treatment methods such as gravitational sedimentation. The releasing water was used as a liquid fertilizer to the agricultural lands.

The solid waste from cow sheds (manure, bedding material and feed residue) was mainly transported using labor power and then used for composting.

3.7 Fulfillment of energy requirement

The main source of energy involved with traditional dairy farms was labor power hence less amount of technological equipments were used. Animals were used for fulfill the requirements in transportation purposes.

Small and self owned hydro power plants were used to supply electricity to the farm. Some extra energy is produced in the bio gas plants which had in very few farms in recent history.

4. Technology and Equipment in Medium and Large Scale Dairy Farms

The technologies and equipments used in dairy farms and dairy processing plants are always tends to be developed day by day. Farmers prefer to invest in machinery and new technologies to the activities in their dairy farms in order to maximize the profit of the farm in many ways such as,

- To maintain the quality of the product
- To increase the productivity
- To lower the human involvement

The main factor that effects the selection of new technologies and machinery is the capacity of the dairy farm. In this chapter, the requirement of technologies and machinery for dairy farms in 3 scales are discussed. The 3 scales of the dairy farms are,

- Small scale dairy farms – Capacity of 20 milking cows
- Medium scale dairy farms – Capacity of 100 milking cows
- Large scale dairy farms – Capacity of 300 milking cows

4.1 Shed space area

The standard dimensions for the cow sheds in free movements of the cows are mentioned in the Table 7.

Animal Type	**Age (months)**	**Weight (kg)**	**Bedded shed area per animal (m^2)**		**Free stalls dimensions (m)**	
			A	**B**	**Length**	**Width**
Calves	1.5 – 3	70 – 100	1.5	1.4	1.2	0.6
Calves	3 – 6	100 – 175	2.0	1.8	1.5	0.7
Calves	6 – 12	175 – 200	2.5	2.1	1.8	0.8
Heifers	12 – 18	250 – 350	3.0	2.3	1.8	0.9
Pregnant cows		400 – 500	3.5	2.5	2.1	1.1
Milking cows		500 – 600	4.0	3.0	2.2	1.2

Table 7: Standard shed space area

A – Enclosed and fully covered bedded shed

B – Bedded shed in conjunction with exercise yard

(Source of information: Farm structures in tropical climates [8] by Lennart P. Bengtsson, James H. Whitaker)

4.1.1 Shed space area for dairy farms

The required shed space depends on the stage of the animals. The shed space area required for small scale, medium scale and large scale dairy farms are mentioned in Table 8.

	Small Scale	**Medium Scale**	**Large Scale**
No. of milking cows	20	100	300
Shed space area (4m^2/animal)	80	400	1200
No. of calves	3	15	45
Shed space area (2m^2/animal)	6	30	90
No. of heifers	3	15	45
Shed space area (3m^2/animal)	9	45	135
No. of pregnant cows	6	30	90
Shed space area (3.5m^2/animal)	21	105	315
No. of dry cows	4	20	60
Shed space area (3m^2/animal)	12	60	180
Total shed space (m^2)	**128**	**640**	**1920**

Table 8: Shed space area for dairy farms

4.2 Machinery and Equipment

Machinery and equipment for the proposed farm should be selected based on several factors;

1. Capital cost

Capital cost includes all the investments done by the farmer at the beginning of the dairy farm. Farmer has to invest for land, animals, feeding methods, forage, milking equipment, storage facilities and waste management systems to own his dairy farm.

2. Time consumption per milking

Time consumption per milking depends on the farmer's preference and other daily activities he has to do. Average time consumption per milking in modern dairy farms varies from 2.5 hours to 3 hours. Time consumption per milking is also an important factor to decide the number of milkings per day. Most of modern farmers' prefer to have 3 times milking per day in order to increase their income from the dairy farm and hence time consumption per 1 milking should be minimized.

3. Maintenance cost

To maximize the profit from the income all the costs should be minimized while all the incomes are maximized. Maintenance cost is a considerable cost factor in modern dairy farms because there are many types of machinery involved with all the processes in the dairy farms compared to past dairy farms.

4. Human involvement

Human involvement is decreased with the introduction of machinery and technological equipments in modern dairy farms. Also there is a considerable difference in the human involvement in activities of dairy farms in developing countries and developed countries. Farmers in developed countries have more difficulties to find employees to activities of their farms.

4.2.1 Major Machinery and Equipment for the Farm

There are many machinery are used in modern farms in all the activities of milking and caring animals. The major machinery and equipment used in the modern farms are,

1) Milking parlor
2) Cooling facility

3) Storage tanks
4) Disinfection
5) Feeders
6) Waste management system

Selection of each machinery and equipment can be done for small scale, medium scale and large scale farms separately.

4.2.2 Selection of Milking Parlor

Selection of milking parlor depends on many factors. Milking parlor type is the first consideration in designing a milking center. Parlor type influences milking center size, layout, location, cow traffic patterns, and milking routine as well as the amount of mechanization that can be used effectively.

1) Number of cows to be milked – Parlor selection depends primarily on the number of cows to be milked. Another important consideration is the performance, or throughput, measured as cows milked per hour. Factors which influence performance include the milk production level, cow preparation routine, parlor pressure, number of milkers, parlor age and design, and milking frequency.
2) Capital cost – The initial investment for the farm and machinery is one of decision of the farmer. Farmer can decide the type of the milking parlor and its capacity depending on his initial investment.
3) Labor operation – Since milking is a labor intensive operation, improvements in milking efficiency can add up to significant savings. Milking parlor automation will depend on parlor size, available labor, initial investment, and personal preference.
4) Waiting area – Waiting area is required with a minimum of 1.5 square meter per cow.

4.2.2.1 Machinery and equipment for small scale farm

1) Milking parlor – Usage of a milking parlor for small scale farm will not be worthwhile. Labor power will be main involvement in the milking process.
2) Cooling facility – To maintain better quality and hygienic conditions of the product, milk should be cooled to 4 ºC in minimum time. Domestic refrigerator with capacity of 400 liter is recommended for the small scale farm to cooling process.

3) Storage tank – Milk can be stored same refrigerator after cooling until it transport to the next stage of manufacturing facility.

4) Disinfection – Since the minimum machinery and equipment are involved with small scale farms, disinfection can be done manually using labor power. All the employees should be well trained about the usage of disinfection activities within the dairy farm.

5) Feeders – Small scale feed mixer can be used to mix and prepare the feed. Capacity with 1 metric ton feed mixer can be used for this purpose. Tractor with a trailer can be used for distribution of feed.

6) Waste management system – Labor power can be used to remove manure and clean the cow sheds daily.

4.2.2.2 Machinery and equipment for medium scale farm

1) Milking parlor – Milking parlor is the key operation unit in the dairy farm. The selection of required milking parlor can be done by using Appendix 05. The recommended milking parlors are,

- Side by side milking parlor with capacity of 2 x 5
- Swing over milking parlor with capacity of 2 x 8
- Auto tandem milking parlor with capacity of 2 x 4

2) Cooling facility – Selection of cooling facility with detailed calculations is done in Chapter 05. The required specifications of the cooling system for medium scale dairy farm are,

- Pre cooling water requirement = 0.65 kgs^{-1}
- Ice bank water requirement = 0.675 kgs^{-1}
- Total power requirement = 10.11 kW

3) Storage tank – The required capacity of storage tank is 2000 liter for medium scale dairy farm.

4) Disinfection – Semi automated system is suitable for medium scale dairy farm. Disinfection of teats can be done manually while the disinfection of other units (cooling unit, storage tank, pipelines) can be done using automated mechanical system using recommended chemicals.

4.2.2.3 Machinery and equipment for large scale farm

1) Milking parlor – High capacity of milking parlor is required for milking in this kind of dairy farm. The recommended milking parlors are, (Appendix 05)

- Side by side milking parlor with capacity of 2 x 16
- Swing over milking parlor with capacity of 2 x 24
- Rotary milking parlor (Herringbone) with capacity of 32
- Rotary milking parlor (Parallel) with capacity of 28

2) Cooling facility – Selection of cooling facility with detailed calculations is done in Chapter 05. The required specifications of the cooling system for large scale dairy farm are,

- Pre cooling water requirement = 1.95 kgs^{-1}
- Ice bank water requirement = 2.025 kgs^{-1}
- Total power requirement = 30.32 kW

3) Storage tank – The required capacity of storage tank is 6000 liter for large scale dairy farm.

4) Disinfection – Semi automated system is suitable for large scale dairy farm as well. Disinfection of teats can be done manually while the disinfection of other units (cooling unit, storage tank, pipelines) can be done using automated mechanical system using recommended chemicals.

5. Technical parameters of Milking parlor, Milk cooling and Storage

Milking parlor is the most important section in a dairy farm. In this diploma thesis, much attention was given to the activities and processes in the herringbone milking parlor. In this chapter technical parameters and specifications required for the operations in milking parlor, milk cooling and milk storage are discussed.

5.1 Types of milking parlors

There are several types of milking parlors. Milking parlors can be categorized mainly into its mobility, organization and shape. The classification of the milking parlors can be summarized as in Figure 7.

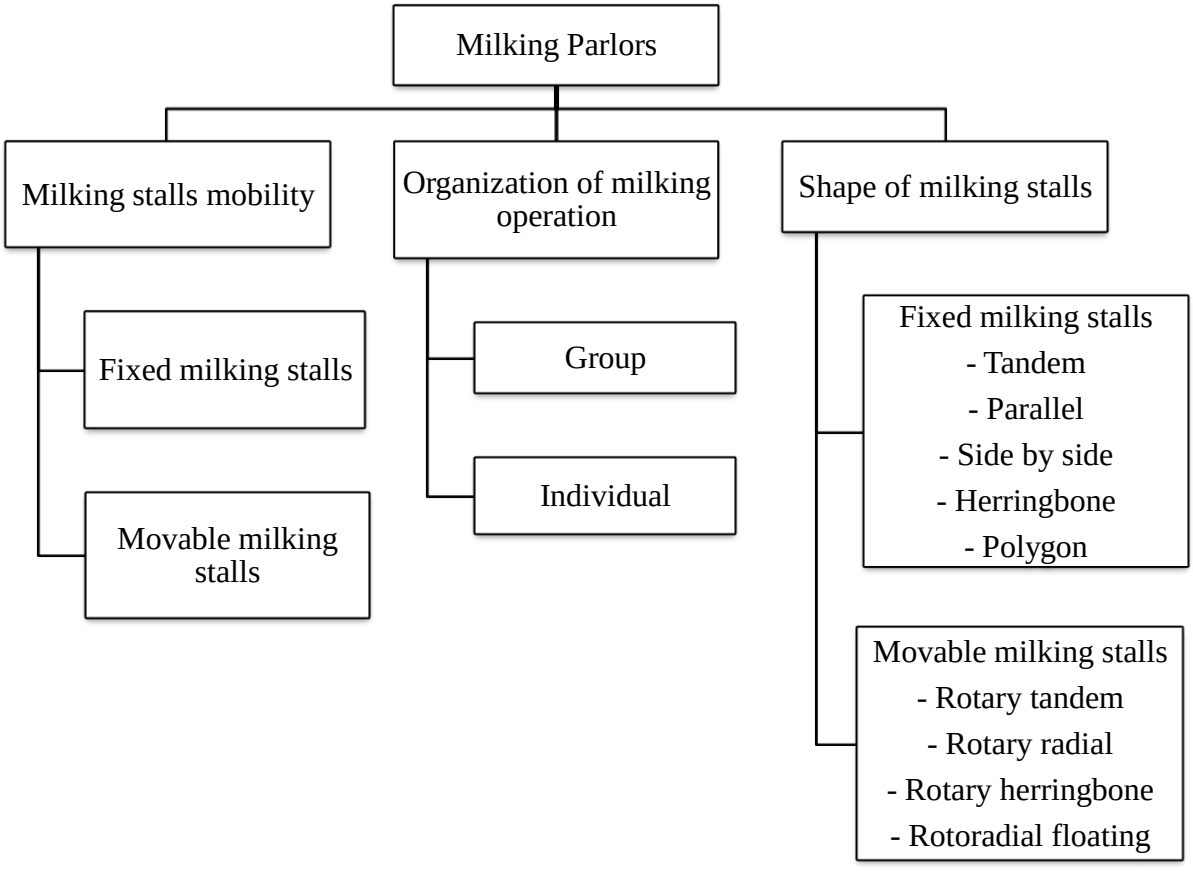

Figure 7: Classification of milking parlors

5.2 Optimization of Herringbone milking parlor

5.2.1 Measures of milking parlor efficiency

Time consumption in human activities involved with milking parlor is the key factor of measurement in milking parlor efficiency.

The table in the Appendix 03 shows the time measurements in the human activities in a dairy farm. The average values of time measurements are shown in Table 9.

Activity	Average Time consumption (second / cow)	Time consumption per batch (second / 11 cows)
1. Entering from gate no.2 to milking parlor	5	55
2. Check sample and pre dip of teats	8	88
3. Wipe the udder with wet cloth	6	66
4. Fix cluster	9	99
5. Getting milk (not human activity)	275	275
6. Remove cluster	4	44
7. Post dip of teats	4	44
8. Exit of cows	6	66
Average time consumption		737
10 % extra time for miscellaneous activities		73
Total time consumption		**810**

Table 9: Average time consumption of the activities in milking parlor

5.2.2 Calculated parameters of milking parlor efficiency [9]

There are several factors are used to measure the efficiency of the human activities in the milking parlor.

- Number of turns per hour
- Gate up to last on time
- Time consumption per cow by milker
- Number of cows per milker in hour

The definitions for these parameters and calculations for the measured values in the dairy farm are mentioned in below.

A) Number of turns per hour – Time consumption in between 2 consecutive openings of the entry gate in same side.

$$\text{Number of turns per hour} = \frac{3600}{t_{Total}}$$

Where,

t_{Total} = Total time consumption [s]

Number of turns per hour = 4.44

B) Gate up to last on time – Time consumption from the time the entry gate is opened and the last milking unit (cluster) is attached.

$$\text{Gate up to last on time} = t_1 + t_2 + t_3 + t_4$$

Where,

t_1 = Entering time to milking parlor

t_2 = Time for check sample and pre dip of teats

t_3 = Time for Wipe the udder with wet cloth

t_4 = Time for fix cluster

Gate up to last on time = 55 + 88 + 66 + 99

= 308 second

C) Time consumption per cow by milker

$$\text{Time consumption per cow by milker} = t_1 + t_2 + t_3 + t_4 + t_5 + t_6 + t_7$$

Where,

t_1 = Entering time to milking parlor

t_2 = Time for check sample and pre dip of teats

t_3 = Time for Wipe the udder with wet cloth

t_4 = Time for fix cluster

t_5 = Time for remove cluster

t_6 = Time for post dip of teats

t_7 = Time for exit of cow)

Time consumption per cow by milker = 5 + 8 + 6 + 9 + 4 + 4 + 6

= 42 second

Time consumption with +10 % time for miscellaneous activities = 46 second

D) Number of cows per milker in hour

$$\text{Number of cows per milker in hour} = \frac{3600}{t_{milker}}$$

Where,

t_{milker} = Time consumption per cow by milker

Number of cows per milker in hour = 78

E) Graphical interpretation of time consumption

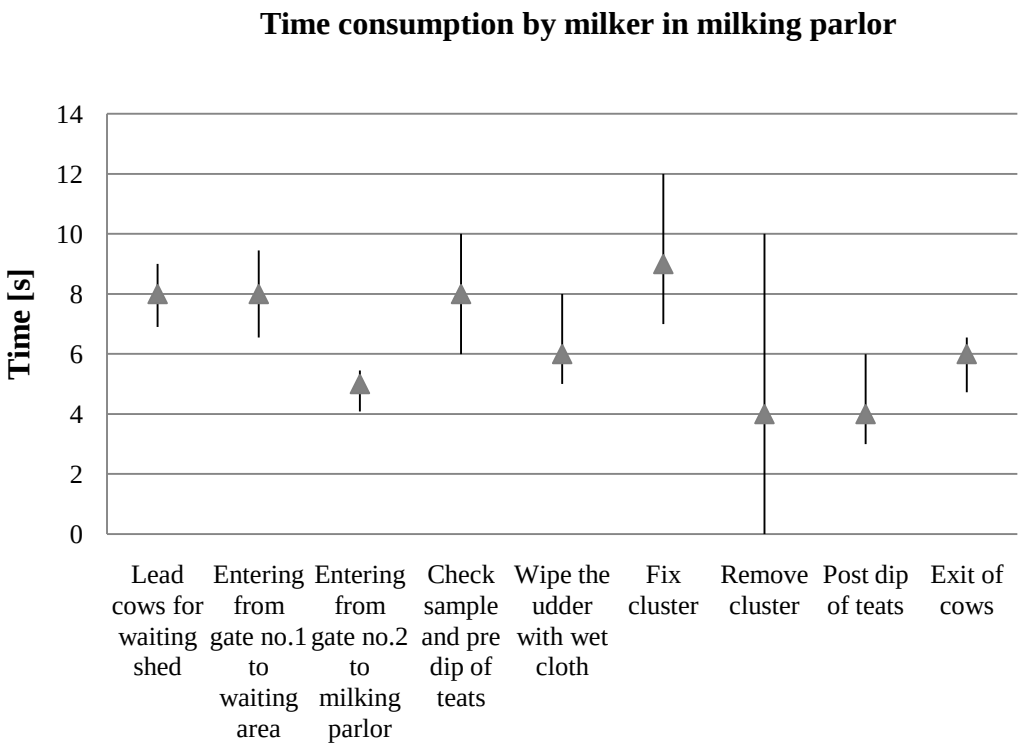

Figure 8: Time consumption by milker in milking parlor

5.3 Economic analysis

Economic analysis is done for dairy farms which are having the capacities of 100 or more milking cows using the simulation of Microsoft Excel. In here, the economic analysis for a dairy farm which is having the capacity of 100 milking cows and Herringbone milking parlor is mentioned.

5.3.1 Economic Analysis of the milking farm (Herringbone milking parlor)

	Type of the milking parlor	2	x	5	
1	No. of milking stalls	10			
	Expected milking time	2.5	hours		
	(# Farmer's decision #)				
	Capacity of the milking parlor	47	Cows/hour		
	(# According to the manual guide provided by the producer of milking parlor #)				
	Herd size	100			
2	Real milking time	2.13	hours		
	(# Real milking time should be less than Expected milking time #)				

If Real milking time is higher than Expected milking time, change the variables in Herd size OR Type of milking parlor)

	Space for cow sheds	640	m^2
	(# Refer the table "Space for cow sheds" #)		

5.3.1.1 Initial Investment

3	For cows	100000	USD
	(# Cost of 1 cow = 1000 USD #)		

4	For cow sheds	640000	USD

(# Construction cost of $1m^2$ = 1000 USD #)

5	For land	2400	USD

(# Assumption : Total area required will be 5 times of the area of cow sheds #)

(# Cost of land: 1 hectare = 7500 USD #)

6 For machinery

Milking parlor	80000	USD
Cooling facility Storage tanks	6420	USD
Disinfection unit	0	USD
Feeders	0	USD

(# Price of 1 milking stall = 8000 USD #)

(# http://www.hnleo.com #) (# Depends on capacity of farm #)

Total Initial Investment	**828820**	**USD**

5.3.1.2 Operating costs per year

7 Cost for Raw materials (# Refer the table "Costs for Raw materials" #)

Green fodder	33288	USD
Silage	29127	USD
Concentrated feed	79296	USD

8 Cost for employees

Total no. of employees	10	
Cost for employees	36500	USD

(# Should be decided by the scale of the farm #)

(# Daily payment for an employee = 10 USD #)

9	Cost for utilities	(# Refer the table "Cost for utilities" #)		
		Electricity	9636	USD
		Water	1669	USD
		Fuel	23349	USD
		Detergents	0	USD
	Total operating cost per year		**212865**	**USD**

5.3.1.3 Operating Incomes per year

10	Selling of milk		300000	USD
	(# Selling price of milk : 1l = 0.5 USD #)			
	(#Lactation period = 300 days / year #)			
11	Selling of low yield cows		12000	USD
	(# Selling price of low yield cow = 600 USD #)			
12	Selling of dry manuer as fertilizer		0	USD
	Total operating income per year		**312000**	**USD**
13	**Net cash flow per year**		**99135**	**USD**

5.3.1.4 Calculation of Financial factors

	Life span of buildings and machineries		20	years
14	Pay back period		8.36	Years

15 Net Present Value

Net present value is used to evaluate the project to check its worthwhile of the investment.

Assumptions ;

- Discount rate = 10%
- Lifespan of buildings and machineries = 20 years

Period	Annual Cash flow (USD)	Present value (USD)
0	-828820	-828820
1	99135	90123
2	99135	81930
3	99135	74482
4	99135	67711
5	99135	61555
6	99135	55959
7	99135	50872
8	99135	46247
9	99135	42043
10	99135	38221
11	99135	34746
12	99135	31587
13	99135	28716
14	99135	26105
15	99135	23732
16	99135	21575
17	99135	19613
18	99135	17830
19	99135	16209
20	99135	14736
Net Present Value		**15172**

Table 10: Net present value

16 Internal Rate of Return 10.27%

Internal rate of return is a key index which can be used to measure and compare the profitability of an investment. In here, internal rate of return is calculated using "IRR Function" in Microsoft Excel.

5.3.1 Summary of the Economic Evaluation of the Project

The summary of the economic evaluation for the Herringbone milking parlor with capacity of 2 x 5 for a dairy farm with 100 milking cows is shown in the Table 11.

Description	**Value**	**Unit**
Initial Investment	828820	USD
Operating cost per year	212865	USD
Operating income per year	312000	USD
Net Cash flow of the year	99135	USD
Pay back period	8.36	Years
Net present value	15172	USD
Internal rate of return	10.27%	

Table 11: Summary of the economic evaluation

5.3.2 Manual Guide for Herringbone Milking Parlor provided by GEA

Type	No. of employees	Capacity (Cows/hour)	Dimensions (m)															
			EuroClass 1200								EuroClass 800							
			1		2		3		4		1		2		3		4	
			L	W	L	W	L	W	L	W	L	W	L	W	L	W	L	W
2 x 3	1	30	5.65	5.00	6.90	5.00	7.65	5.00	6.50	5.00								
2 x 4	1	38	6.85	5.00	8.10	5.00	8.85	5.00	7.70	5.00								
2 x 5	1	47	8.05	5.00	9.30	5.00	10.05	5.00	8.90	5.00	6.05	6.00	7.30	6.00	8.55	6.00	7.30	6.00
2 x 6	1	56	9.25	5.00	10.50	5.00	11.25	5.00	10.10	5.00	6.85	6.00	8.10	6.00	9.35	6.00	8.10	6.00
2 x 7	1 to 2	66	10.45	5.00	11.70	5.00	12.45	5.00	11.30	5.00	7.65	6.00	8.90	6.00	10.15	6.00	8.90	6.00
2 x 8	1 to 2	73	11.65	5.00	12.90	5.00	13.65	5.00	12.50	5.00	8.45	6.00	9.70	6.00	10.95	6.00	9.70	6.00
2 x 10	2	90	14.05	5.00	15.30	5.00	16.05	5.00	14.90	5.00	10.05	6.00	11.30	6.00	12.55	6.00	11.30	6.00
2 x 11	2	97	15.25	5.00	16.50	5.00	17.25	5.00	16.10	5.00	10.85	6.00	12.10	6.00	13.35	6.00	12.10	6.00
2 x 12	2	105	16.45	5.00	17.70	5.00	18.45	5.00	17.30	5.00	11.65	6.00	12.90	6.00	14.15	6.00	12.90	6.00
2 x 13	2	112	17.65	5.30	18.90	5.30	19.65	5.30	18.50	5.30	12.45	6.30	13.70	6.30	14.95	6.30	13.70	6.30
2 x 14	2	120	18.85	5.30	20.10	5.30	20.85	5.30	19.70	5.30	13.25	6.30	14.50	6.30	15.75	6.30	14.50	6.30
2 x 15	2 to 3	128	20.05	5.30	21.30	5.30	22.05	5.30	20.90	5.30	14.05	6.30	15.30	6.30	16.55	6.30	15.30	6.30
2 x 16	2 to 3	137	21.25	5.30	22.50	5.30	23.25	5.30	22.10	5.30	14.85	6.30	16.10	6.30	17.35	6.30	16.10	6.30
2 x 18	3	152	23.65	5.50	24.90	5.50	25.65	5.50	24.50	5.50	16.45	6.50	16.90	6.50	18.95	6.50	17.70	6.50
2 x 20	3	170	26.05	5.50	27.30	5.50	28.05	5.50	26.90	5.50	18.05	6.50	19.30	6.50	20.55	6.50	19.30	6.50
2 x 22	3	185									19.65	6.50	20.90	6.50	22.15	6.50	20.90	6.50
2 x 24	3										21.25	6.50	22.50	6.50	23.75	6.50	22.50	6.50

Table 12: Manual Guide for Herringbone Milking Parlor provided by GEA

5.3.3 Space for cow sheds

Space for cow sheds is a function of number of animals and animal types. Table 13 shows the required space for cow sheds for small scale, medium scale and large scale dairy farms.

	Small Scale	**Medium Scale**	**Large Scale**
No. of milking cows	20	100	300
Shed space area (4m^2/animal)	80	400	1200
No. of calves	3	15	45
Shed space area (2m^2/animal)	6	30	90
No. of heifers	3	15	45
Shed space area (3m^2/animal)	9	45	135
No. of pregnant cows	6	30	90
Shed space area (3.5m^2/animal)	21	105	315
No. of dry cows	4	20	60
Shed space area (3m^2/animal)	12	60	180
Total shed space (m^2)	**128**	**640**	**1920**

Table 13: Space for cow sheds

5.3.4 Raw materials requirement

These calculations based on,

- Cows require green fodder 8% - 10% and silage 3% - 4%of their body weight
- Concentrated feed is only for heifers and milking cows and 1 kg for 3 liters of milk

5.3.4.1 Green Fodder

	Small Scale	**Medium Scale**	**Large Scale**
No. of milking cows	20	100	300
Green fodder (40 kg / Animal)	800	4000	12000
No. of calves	3	15	45
Green fodder (8 kg / Animal)	24	120	360
No. of heifers	3	15	45

Green fodder (24 kg / Animal)	72	360	1080
No. of pregnant cows	6	30	90
Green fodder (32 kg / Animal)	192	960	2880
No. of dry cows	4	20	60
Green fodder (32 kg / Animal)	128	640	1920
Total Green Fodder (kg/day)	**1216**	**6080**	**18240**
Cost (USD/year)	**8876.8**	**44384**	**133152**

Table 14: Requirement of green fodder

Additional data:

Price of green fodder in SL : 1000 kg = 20USD

5.3.4.2 Silage

	Small Scale	Medium Scale	Large Scale
No. of milking cows	20	100	300
Silage (15 kg / Animal)	300	1500	4500
No. of calves	3	15	45
Silage (3 kg / Animal)	9	45	135
No. of heifers	3	15	45
Green fodder (9 kg / Animal)	27	135	405
No. of pregnant cows	6	30	90
Silage (12 kg / Animal)	72	360	1080
No. of dry cows	4	20	60
Silage (12 kg / Animal)	48	240	720
Total Silage (kg/day)	**456**	**2280**	**6840**
Cost (USD/year)	**5825.4**	**29127**	**87381**

Table 15: Requirement of silage

Additional data:

Price of silage in SL : 1000 kg = 35USD

5.3.4.3 Concentrated feed

	Small Scale	Medium Scale	Large Scale
No. of milking cows	20	100	300
Concentrated feed (7 kg / Animal)	140	700	2100
No. of pregnant cows	6	30	90
Concentrated feed (3 kg / Animal)	18	90	270
Total Concentrated feed (kg/day)	**158**	**790**	**2370**
Cost (USD/year)	**15859.25**	**79296.25**	**237888.75**

Table 16: Requirement of concentrated feed

Additional data:

Price of concentrated feed in SL : 1000 kg = 275USD

5.4 Milk cooling

Milk cooling is the most important unit operation after the milking in the milking parlor. Milk is highly perishable food because of its high microbial content. In order to maintain better quality of milk, it should be cooled to 4 ºC as soon as possible.

Figure 9 shows the flow of milk after milking in the milking parlor with cooling and final storage in dairy farm until it is transported to the dairy manufacturing facility.

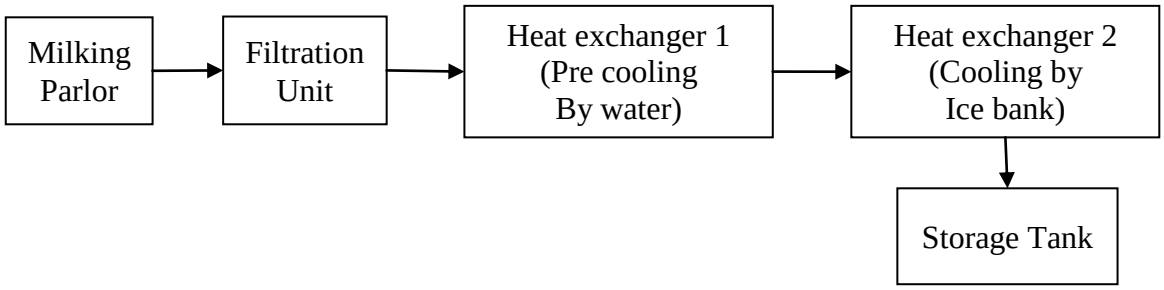

Figure 9: Block diagram of milk cooling

5.4.1 Temperature changes in heat transfer

Since there are 2 heat exchangers are used to reduce the power consumption, it is important to consider both of these heat exchangers separately. Table 17 and Table 18 show the changes in temperatures of heat exchanger 1 and heat exchanger 2 respectively.

5.4.1.1 **Heat exchanger 1**

Heat Exchanger 1			
Raw milk		Water	
Inlet (ºC)	Outlet(ºC)	Inlet(ºC)	Outlet(ºC)
35	30	20	26

Table 17: Temperature changes in heat exchanger 1

5.4.1.2 **Heat exchanger 2**

Heat Exchanger 2			
Raw milk		Ice bank water	
Inlet(ºC)	Outlet(ºC)	Inlet(ºC)	Outlet(ºC)
30	4	0	3

Table 18: Temperature changes in heat exchanger 2

5.4.2 Other parameters used for calculation [10]

Density of cow milk (ρ_{milk}) = 1033 kgm^{-3}

Volumetric flow rate of cow milk (V) = 6000 l/cow. year

Specific heat capacity of cow milk (c_1) = 3770 J/kg ºC

Number of milking cows in the farm = N **(N ≥ 100)**

Specific heat capacity of water (c_2) = 4184 J/kg ºC

Mass flow rate of water = $\dot{m}_1$ kg/s

Mass flow rate of ice water = $\dot{m}_2$ kg/s

5.4.3 Assumptions

- Average values are used for specific heat capacities of cow milk and water.
- The effect of temperature on the average values used in here is neglected.
- There are 2 times milking per day in the farm. (2 shifts)
- Time used for 1 milking is considered as 3 hours
- 10% of energy is wasted during the heat transfer

5.4.4 Calculation

Calculation for the cooling process for milk is done basically for main 2 requirements,

- Cooling water flow rate requirement
- Power requirement

5.4.4.1 Cooling water flow rate requirement

Volume of total cow milk per year = 6000N liter/year

Mass of cow milk per shift = $\frac{6000\,\mathrm{N}\times10^{-3}\times1033}{365\times2}$ kg/shift

Heat transfer is calculated by using the equation,

$$Q = mc\theta \qquad (1)$$

Where,

Q = Amount of heat transferred [J]

m = Mass of the object [kg]

c = Specific heat capacity [$Jkg^{-1}{}^{o}C^{-1}$]

θ = Change of temperature [ºC]

Differentiate the equation (1) with respect to the time,

$$\frac{dQ}{dt} = \frac{d}{dt}(mc\theta)$$

$$\dot{Q} = \dot{m}c\theta \qquad (2)$$

Consider the heat transfer (with 10% of energy wasted during transfer),

$$\text{Power released by milk} \times \frac{110}{100} = \text{Power absorbed by water}$$

$$\dot{m}_1 c_1 \theta_1 \times \frac{110}{100} = \dot{m}_2 c_2 \theta_2 \qquad (3)$$

Where,

$\dot{m}_1, \dot{m}_2 =$ Mass flow rates of milk and water respectively

$c_1, c_2 =$ Specific heat capacities of milk and water respectively

$\theta_1, \theta_2 =$ Temperature changes of milk and water respectively

1) <u>Pre cooling of milk by water in room temperature</u>

Substitute the values to the equation (3),

$$\dot{m}_1 = 6.4933 \times 10^{-3} N \text{ kgs}^{-1}$$

2) <u>Further cooling of milk by ice bank</u>

Substitute the values to the equation (3),

$$\dot{m}_2 = 6.7529 \times 10^{-3} N \text{ kgs}^{-1}$$

3) Cooling of milk using only ice bank

Substitute the values to the equation (3),

$$\dot{m}_3 = 8.0517 \times 10^{-3} N \text{ kgs}^{-1}$$

5.4.4.2 Power requirement

1) Pre cooling of milk by water in room temperature

Substitute values to the equation (2),

$$\dot{Q}_1 = 16.30N \text{ W}$$

2) Further cooling of milk by ice bank

Substitute values to the equation (2),

$$\dot{Q}_1 = 84.76N \text{ W}$$

3) Cooling of milk using only ice bank

Substitute values to the equation (2),

$$\dot{Q}_1 = 101.06N \text{ W}$$

5.4.5 Summary of the results

Table 19 illustrates the summarization of the results in the calculation for cooling of milk.

Capacity of the farm	Number of milking cows	Per cooling water requirement (kgs^{-1})	Ice bank water requirement (kgs^{-1})	Total power requirement (kW)
Small scale	20	--	0.16	2.02
Medium scale	100	0.65	0.675	10.11
Large scale	300	1.95	2.025	30.32

Table 19: Summary of the calculation for milk cooling

5.4.5.1 Graphical interpretation of flow rate of cooling water

Figure 10 illustrates the relation between number of cows in the dairy farm and the flow rates of cooling water in milk cooling.

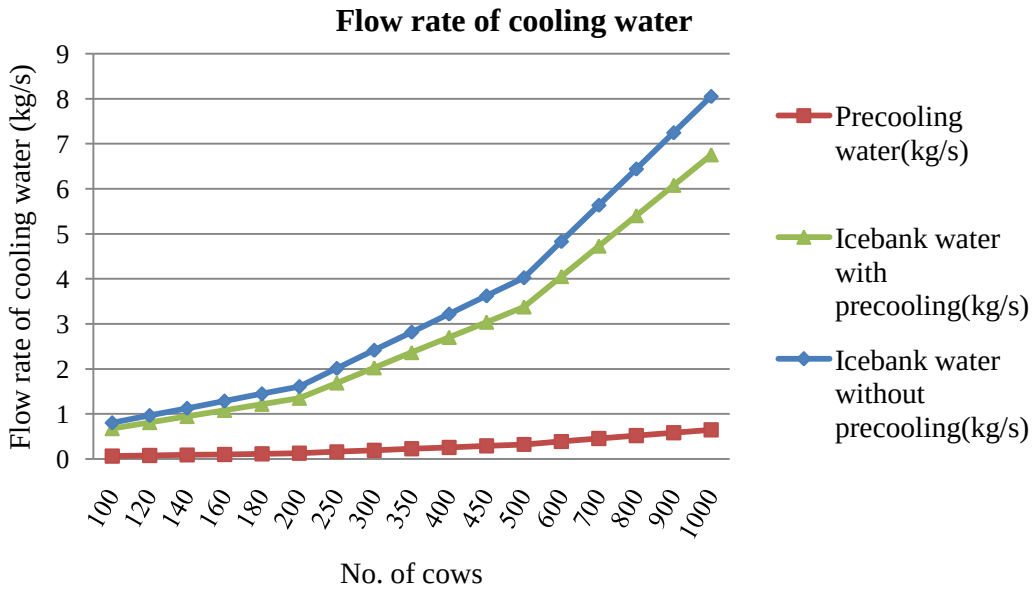

Figure 10: Graphical interpretation of flow rate of cooling water

5.5 Milk storage

5.5.1 Required capacities

Assumptions:

- There are 2 shifts are operating per day
- 20% more capacity for future requirements in each tank

Total volume of cow milk = 6000N liter/year

Total volume of cow milk per shift $= \frac{6000\,N}{365 \times 2}$ liter/shift

= 8.2192N liter/shift

Capacity of milk storage tanks is a function of number of milking cows. The required capacities of milk storage tanks for small scale, medium scale and large scale dairy farms can be summarized as in Table 20.

Description	Small scale	Medium scale	Large scale
Number of milking cows	20	100	300
Capacity of 1 storage tank	400 liter	2000 liter	6000 liter
Number of storage tanks	1	1	1

Table 20: Required capacities of milk storage tanks

5.5.2 Insulation of storage tanks

Insulation of storage tank is helpful to maintain the temperature in the milk which is cooled by the heat exchangers. However some of the heat will be loss through the wall of storage tank and to maintain the temperature in the milk that heat should be supplied to the storage tank. The insulation of the storage tank should be designed such that the heat loss through its walls will be minimum.

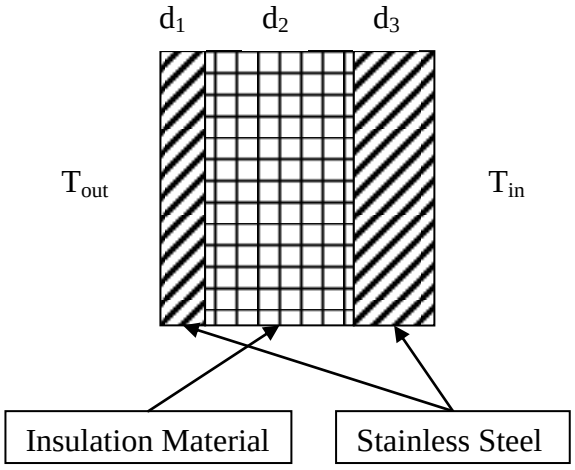

Figure 11: Insulation of storage tanks

5.5.3 Parameters used for calculation [10] [11]

Interior temperature of storage tank (T_{in})	= 4 ºC
Room temperature (T_{out})	= 25 ºC
Heat transfer coefficient of air (α_{air})	= 12 $Wm^{-2}K^{-1}$
Heat transfer coefficient of liquid (α_{liquid})	= 300 $Wm^{-2}K^{-1}$
Heat transfer coefficient of stainless steel (λ_{steel})	= 16.5 $Wm^{-1}K^{-1}$
Heat transfer coefficient of polyurethane foam (λ_{PU})	= 0.03 $Wm^{-1}K^{-1}$

Thickness of exterior steel plate of storage tank (d_1) = 0.5 mm

Thickness of interior steel plate of storage tank (d_3) = 2.0 mm

5.5.4 Assumptions

- Surface area of heat flow (A) = 1 m^2

5.5.5 Calculation

Basic heat loss (Q_o) is given by,

$$Q_0 = \sum U_k \times A_j \times (T_{out} - T_{in}) \qquad (3)$$

Where,

U_k = Overall heat transfer coefficient ($Wm^{-2}K^{-1}$)

A_j = Surface area of heat transfer

T_{out} = Outside temperature of the storage tank

T_{in} = Inside temperature of the storage tank

Overall heat transfer coefficient (U_k) is calculated by,

$$U_k = \frac{1}{\frac{1}{\alpha_{liquid}} + \sum \frac{d}{\lambda} + \frac{1}{\alpha_{air}}} \qquad (4)$$

Where,

α_{liquid} = Heat transfer coefficient of liquid

d = Thicknesses of stainless steel plates and insulation material

λ = Heat transfer coefficients of steel and insulation material (polyurethane foam)

α_{air} = Heat transfer coefficient of air

By substituting values for equation (4),

$$U_k = \frac{1}{0.0867 + 41250 + 30d_2} \ Wm^{-2}K^{-1}$$

By substituting U_k to the equation (3),

$$Q_0 = \frac{21}{0.0867 + 41250 + 30d_2} \ Wm^{-2}$$

5.5.6 Heat loss of storage tank

Figure 12 shows the change of heat loss through the walls of storage tanks to the environment with the thickness of the insulation material. In here, polyurethane foam is used as the insulation material which has 0.03 $Wm^{-1}K^{-1}$ thermal conductivity.

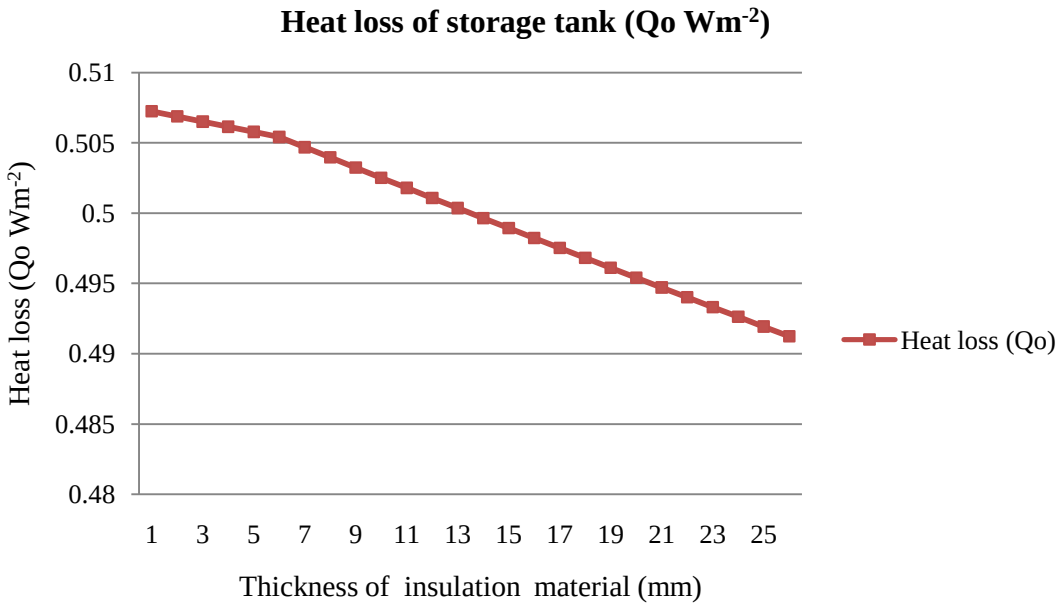

Figure 12: Heat loss of storage tank

6. Milk processing and distribution in progressive commercial industrial chains

6.1 Milk reception

Milk is brought from the farm to the dairy for processing using tankers. When received at the dairy processing plant, the following information of the milk is required.

- Quality – Before weighing the milk at reception point, its quality should be checked. Visual observation, taste and smell are good preliminary indicators of milk quality. If the person who checks these indicators does not satisfy with the quality of the milk, he can recommend the tests to measure the parameters such as acidity, pH, alcohol, and clot on boiling in order to clarify the quality of the milk.
- Weight – The quantity of milk received can be estimated either volumetrically or gravimetrically. Milk processors usually base payments for milk on its solids content, and hence it is more appropriate to use weight to estimate the quantity of milk being tendered.
- Composition – In large dairy plants, milk price is based on the content of the major milk constituents. For small scale milk processors, this is not normally feasible and payment should be based on fat content.
- Presence of contaminants – There may be some contaminants included in raw milk such as neutralizers and preservatives. These should be measured qualitatively and quantitatively before the milk is used in dairy processing.
- Presence of added water

6.1.1 Milk Analysis

Milk analysis is carried out to determine the several parameters in order to clarify the quality of the milk.

- Freshness
- Adulteration
- Bacterial content
- Milk constituents for payment calculation

Milk analysis consists of several steps and these steps may depend on the dairy processing facilities.

1) Sampling – A representative sample is essential for accurate testing. Milk must be mixed thoroughly prior to sampling and analysis to ensure a representative sample. Milk samples can be preserved and stored to await analysis. Most of the time formalin is used as the preservative agent in milk sampling.

2) Measurement of pH – A rough estimate of pH may be obtained using paper strips impregnated with an indicator. Also electrometric pH meters are used to obtain the pH values more precisely.

3) Determination of milk acidity - The percentage of acid present in dairy products at any time is a rough indication of the age of the milk and the manner in which it has been handled. Titration with an alkali agent (NaOH) can be used to determine the acidity of the milk.

4) Alcohol test – The alcohol test is done together with the acidity test. This test is used on fresh milk to indicate whether it will coagulate on processing. Milk that contains more than 0.21% acid, or calcium and magnesium compounds in greater than normal amounts, will coagulate when alcohol is added.

5) Clot on boiling test – The clot on boiling test is used to determine whether milk is suitable for processing, as it indicates whether milk is likely to coagulate during processing. The main advantage of this test is no chemicals are used.

6) Determination of fat content – The main tests used to determine the fat content of milk and milk products are the Gerber and Babcock tests. Automated methods for testing milk are now used in central laboratories and at large processing centers to determine the fat content.

7) Determination of milk specific gravity – Specific gravity is the relation between the mass of a given volume of any substance and that of an equal volume of water at the same temperature. The lactometer is used to measure the specific gravity of the milk. The average value for specific gravity of cow milk is 1.032.

8) Determination of total solids and solids non fat in milk – The only accurate way to determine total solids is by evaporating the water from an accurately weighed sample. Amount of non fat solids can be calculated by reducing the amount of fat content

6.2 Milk processing

After the analysis of the milk at the milk reception, milk is then used to the further processing depending on the results. The following block diagram illustrates the process of a dairy plant in briefly.

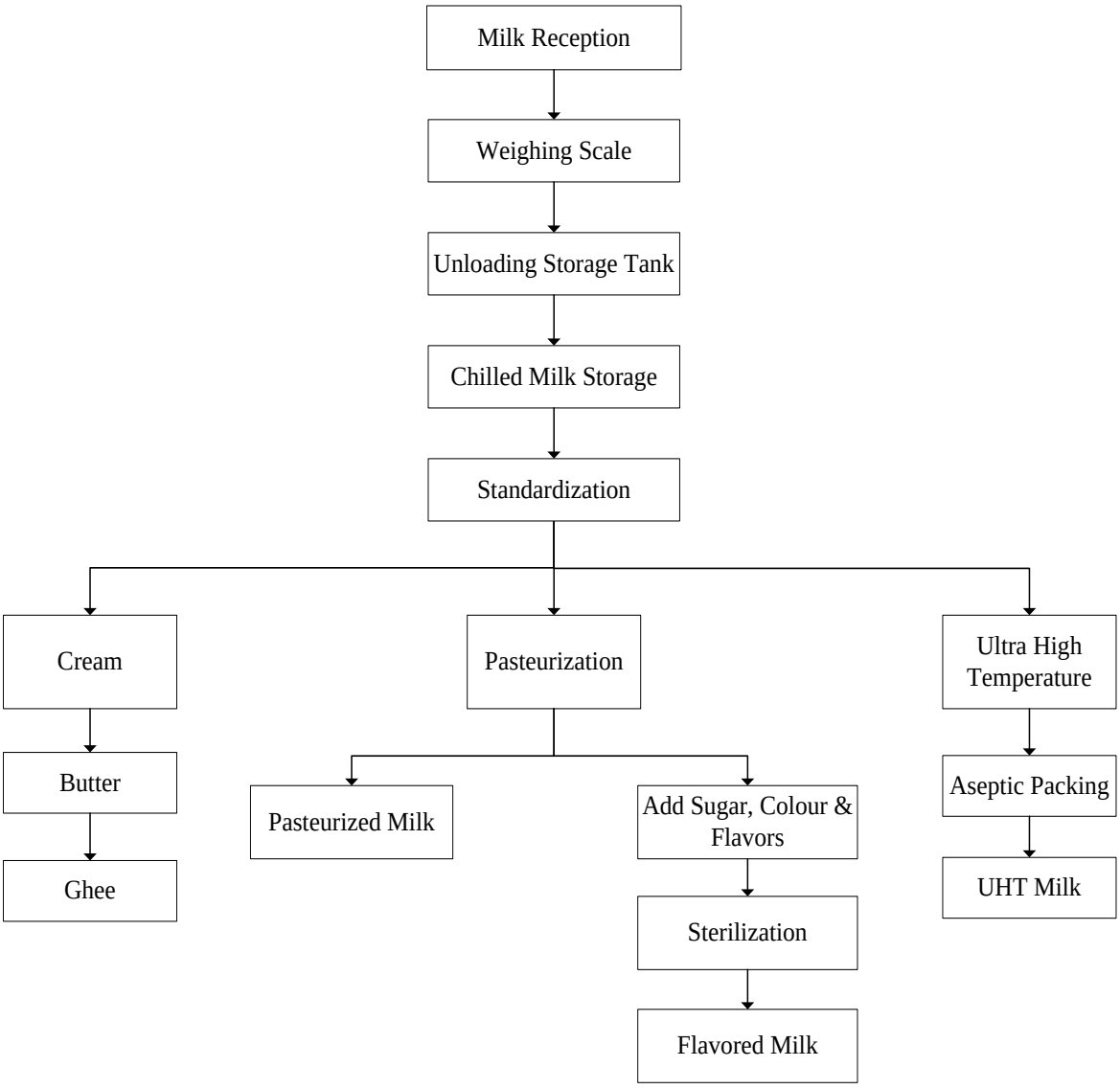

Figure 13: Basic block diagram of milk processing

6.2.1 Standardization of milk

Standardization is defined as the industrial adjustment of milk or cream fat content to a precisely specified or desired value. Standardization should be done prior to milk is used in the dairy processing. Standardization is important in many ways in dairy processing, especially in the maintaining the quality of the final product.

6.2.2 Pasteurization

Pasteurization is the process of heating milk to below the boiling point to destroy microorganisms. There are 2 main purposes of pasteurization of milk.

- To increase milk safety for the consumer by destroying disease causing microorganisms (pathogens) that may be present in milk.
- To increase keeping the quality of milk products by destroying spoilage microorganisms and enzymes that contributes to the reduced quality and shelf life of milk.

Pasteurization mainly depends on 2 factors as temperature and time. There are several types of pasteurizations [12] as illustrated in Table 21.

Pasteurization Type	**Temperature (^{o}C)**	**Time (s)**
Vat pasteurization	63	1800
High temperature short time (HTST)	72	15
Higher heat shorter time (HHST)	89	1
Higher heat shorter time (HHST)	90	0.5
Higher heat shorter time (HHST)	94	0.1
Higher heat shorter time (HHST)	96	0.05
Higher heat shorter time (HHST)	100	0.01

Table 21: Pasteurization types

6.2.3 UHT (Ultra High Temperature) Milk

In UHT treatment [13], milk is exposed to intense heating to temperatures in the range of 135 ^{o}C to 150 ^{o}C for only 2 – 3 seconds. UHT treatment is a continuous process which takes place in a closed system that prevents the product from being contaminated by airborne microorganisms.

The UHT milk passes through heating and cooling stages in quick succession, and then is immediately put into a sterile Tetra Pak shelf safe carton. This process avoids any re infection. The end result is a product that lasts up to six months without refrigeration or preservatives.

6.2.4 Nutritional condition of UHT milk

It is important to consider about the nutritional condition of UHT milk since high temperatures and high pressures are applied in the processing. Table shows the nutritional effects of UHT milk compared to pasteurized milk.

Nutrient	**Effect**
Energy (Calorific value)	UHT milk contains same amount of calories as pasteurized milk
Calcium	UHT and pasteurized milk contains the same amount of calcium
Protein	Protein structure of UHT milk is different from pasteurized milk
Vitamins	Some vitamins loss can be occurred in UHT milk

Table 22: Nutritional condition of UHT milk

6.2.5 Yoghurt

The basic steps involved in yoghurt manufacturing process [14] are,

- Adjust milk composition and blend ingredients – Milk composition should be adjusted to desired values of fat content and solid content.
- Pasteurize the milk – To denature the whey proteins and to form a stable gel.
- Homogenization – To mix all the ingredients thoroughly.
- Cool the milk – To provide optimum temperature for inoculation of culture.
- Inoculate with starter culture – The starter cultures are mixed into the milk.

- Hold for inoculation – The milk is held at 42 ^{o}C until pH value of 4.5 is reached.
- Cool the yoghurt – The yoghurt is cooled to 7 ^{o}C to stop the fermentation.
- Package – Final packaging before send to the market.

6.3 Milk distribution network in Sri Lanka

Milk distribution network is an important figure which illustrates the connection of producer and consumer of the product. Large scale farmers are having their own distribution networks in between their dairy farms and dairy manufacturing plants. Most of small scale and medium scale dairy farmers use cooperative milk distribution network [15] which show in Figure 14.

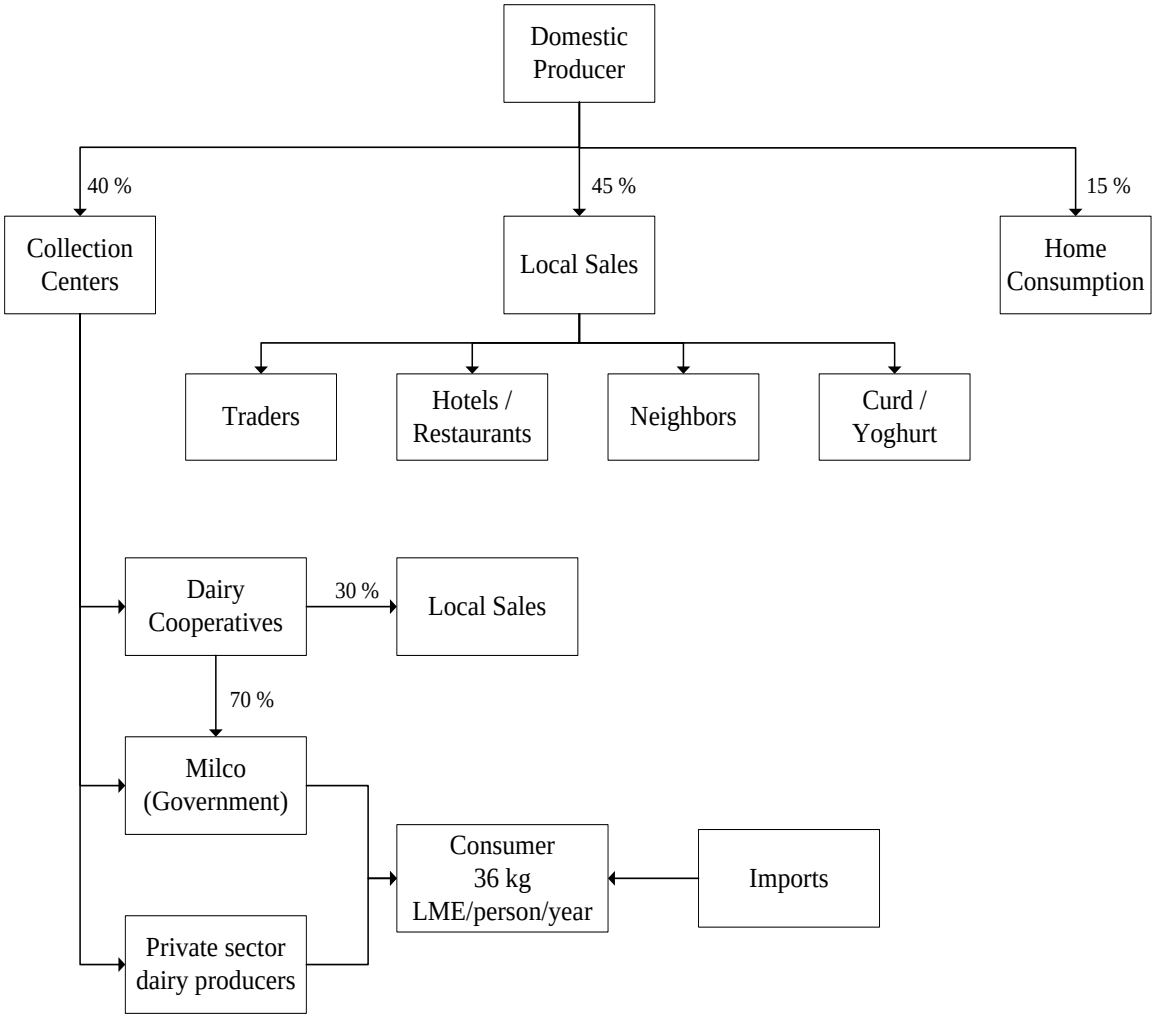

Figure 14: Milk distribution in Sri Lanka

7. Conclusion and Recommendations for Practical Applications

In this chapter, the conclusions from the observations and calculations done in previous chapters are discussed. And also the recommendations for further improvements of dairy farms in Sri Lanka are identified and described briefly.

7.1 Reasons for over time consumption in milking parlor

It is important to identify the reasons for over time consumption in a milking parlor in order to reduce the overall time consumption in dairy farm and then to increase the overall efficiency of all unit operations.

1) Entry time is too high

- Poor working routine
- Poor design of entry
- Slippery floor
- Poor cow handling

2) Udder preparation time is too high

- Dirty udders
- Poor working routine, equipment
- Parlor layout
- Poor cow handling

3) Attach time is too high

- Slow operator
- Lack of routine
- Poor design of equipment
- Kicking cows
- Poor design of parlor

4) Post treatment time is too high

- Work routine (walking)
- Kicking cows
- Location of equipment

5) Miscellaneous time is too high

- Too many interruptions
- Not enough automation
- Milker went in the holding area once
- Too much special care in the parlor

7.2 Recommended dairy farm for Sri Lanka

It is recommended to develop medium scale dairy farms for developing and economically agricultural based countries like Sri Lanka due to several factors such as,

- Economic feasibility – Most of the dairy farmers do not have capability to invest higher capital to their farms. Medium scale dairy farm is recommended for farmers with financial support of the government or any other organization.
- Medium technological involvement – High technological equipment and their spare parts are less available in Sri Lanka. Also farmers should have proper technical knowledge of high technical equipment in order to take maximum usage of equipments, especially their operation and maintenance.
- Suitable for existing milk collection network – Cooperative system is used in many parts of Sri Lanka to collect milk from small scale farmers. Fewer modifications are required to modify the collection network with medium scale dairy farms.
- Availability of labor power – Labor power is available in Sri Lanka and to get maximum advantage of it, medium scale dairy farm is recommended.
- Raw materials supply – Since Sri Lanka is having an agricultural based economy, especially with rice production, hay is available with all around the country. Silage production is low compared to other countries and this should be developed in order to increase the production capacity of milk.
- Land availability – Land is available for medium scale dairy farm all around the country. But it is recommended to select a land from North Western Province, North Central Province or Eastern Province in order to receive raw materials at effective transportation cost.
- Utilities – Ground water is good enough to use in the dairy farm. Other utilities including fuel and electricity are a production cost for the farm. Bio gas plant is recommended to generate extra energy supply for the dairy farm using biological waste in the farm.

7.2.1 Specifications of the recommended dairy farm

1) Animals

- Selected cow type : AFS (Crossed breed of Australian Friesian and Sahiwal)
- Number of milking cows : 100

2) Animal housing

- Total required space for cow sheds : 640 m^2

Type of cows	Number of animals	Number of cow sheds	Area of 1 cow shed (m^2)
Milking cows	100	2	200
Heifers	15	1	45
Pregnant cows	30	1	105
Calves	15	1	30
Dry cows	20	1	60

Table 23: Area for recommended cow sheds

- Construction
    - Construction material for structure : Concrete
    - Construction material for roof : Clay tiles
- Housing technique : Loose housing with straw bedding

3) Raw materials storage

Raw materials storage facility should be required for at least consumption of 1 week.

- Required capacity for green fodder : 40,000 kg
- Required capacity for hay : 20,000 kg
- Required capacity for concentrated feed : 5,000 kg

4) Other machinery

- Feed preparation and distribution : Feed mixture wagon with capacity 3 m^3
- Loader for hay and waste : Capacity 0.5 m^3

5) Milking parlor

One of the following milking parlors can be selected to this kind of dairy farm depending on the preference and the economic capability of the farmer.

- Side by side milking parlor with capacity of 2 x 5

- Swing over milking parlor with capacity of 2 x 8
- Auto tandem milking parlor with capacity of 2 x 4
- Herringbone milking parlor with capacity of 2 x 5

6) Cooling

Pre cooling of milk using water at room temperature is recommended in order to reduce the power consumption in ice bank (water at 0 ^{o}C) cooling.

Pre cooling water requirement : 0.65 kgs^{-1}

Ice bank water requirement : 0.675 kgs^{-1}

Total power requirement for cooling : 10.11 kW

7) Storage tank

- Required capacity of storage tank : 2000 liter

Special attention should be given to the insulation of storage tank since selected area in Sri Lanka has hot climatic condition throughout the year.

8) Waste management

- Holding capacity of waste water treatment plant: 200 m^3
- Capacity of solid waste storage tanks : 40,000 kg

7.2.2 Economical evaluation of the farm

- Initial investment : 828,820 USD
- Operating costs per year : 212,865 USD
- Operating incomes per year : 312,000 USD
- Net cash flow per year : 99,135 USD
- Payback period : 8.36 Years
- Net present value : 15,172 USD
- Internal rate of return : 10.27 %

7.2.3 Recommended area for the dairy farms

North Western, North Central and Eastern provinces are suitable for medium scale dairy farms since the land availability and raw materials availability throughout the year. The required area for 1 farm is 2 hectares including area to grow green fodder for the farm. Figure

15 shows the recommended area for the dairy farms in Sri Lanka. This area includes following administrative districts,

- Puttalam
- Kurunegala
- Anuradhapura
- Polonnaruwa
- Trincomalee
- Ampara

Figure 15: Recommended area for dairy farms

7.3 Construction of medium scale dairy farm

7.3.1 Animal housing for proposed dairy farm

Lose housing with pens is recommended. Natural ventilation can be used and therefore no need any ventilation fans or blowers to the proposed dairy farm. Following figures show cross view (Figure 16) and plan (Figure 17) of the animal house which has capacity of 100 milking cows in the dairy farm.

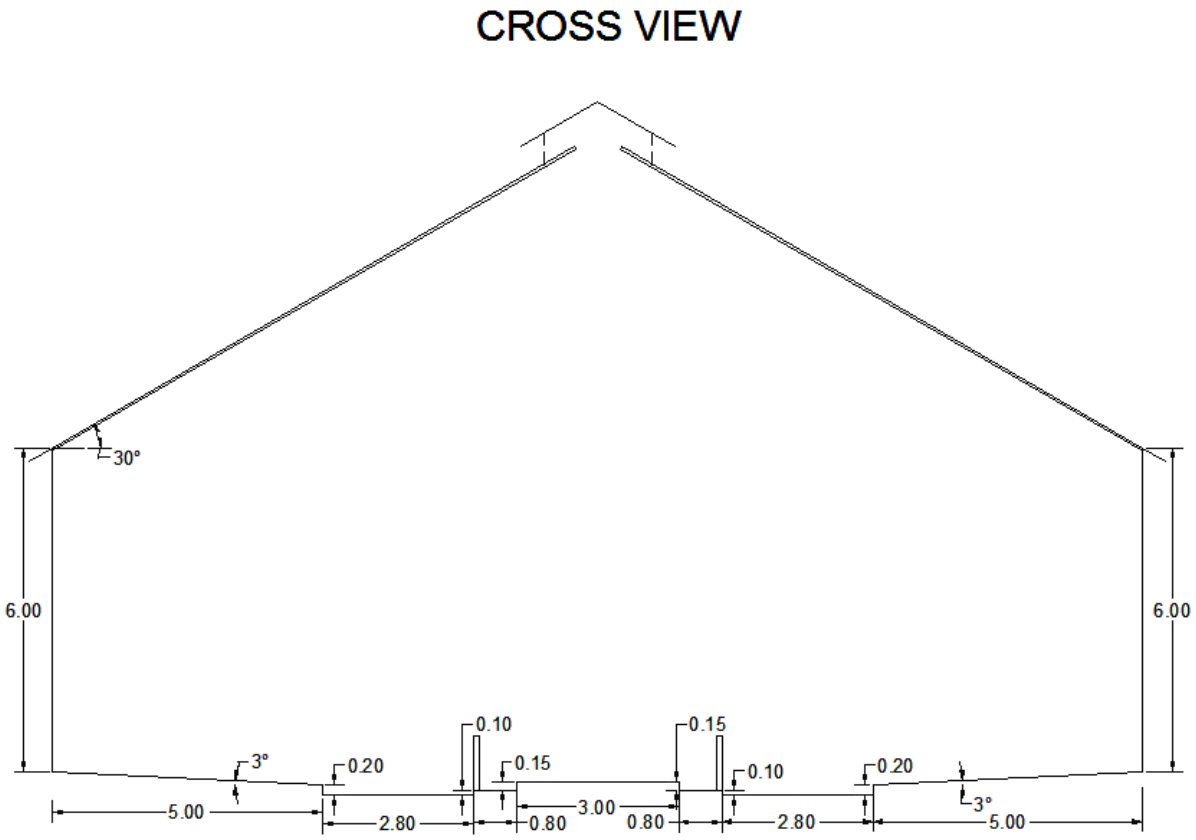

Figure 16: Cross view of the cattle house

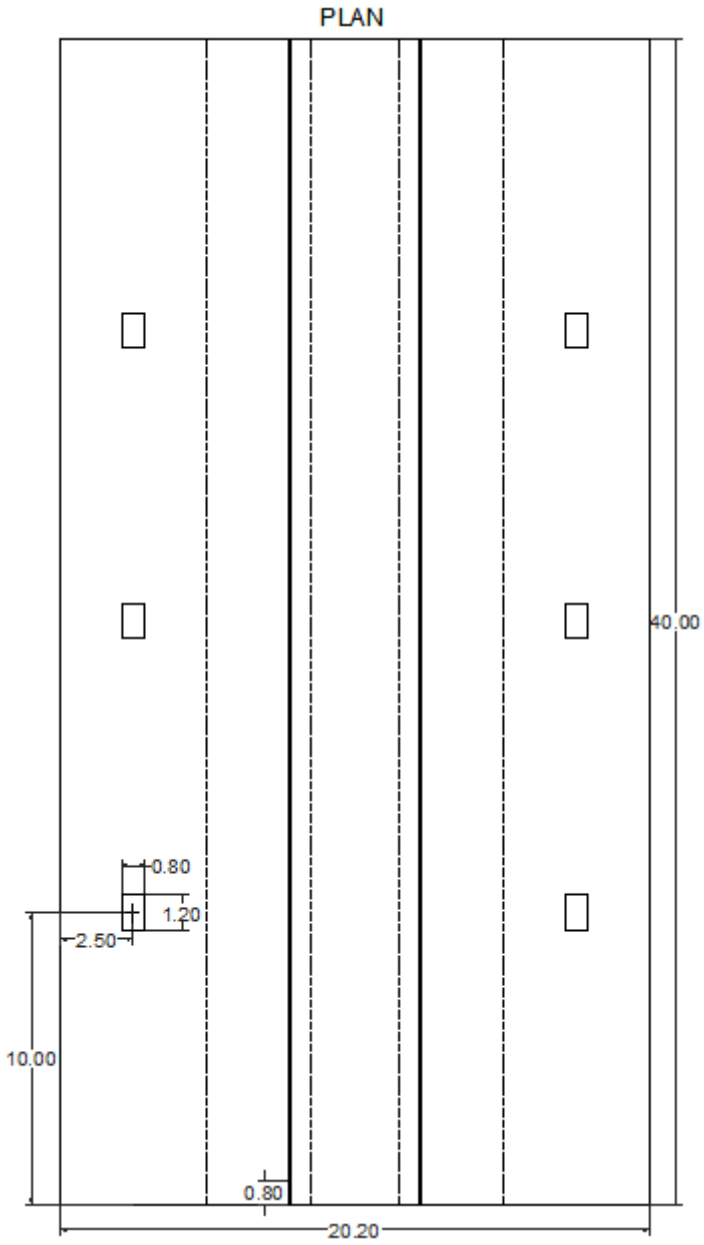

Figure 17: Plan of the cattle house

7.3.2 Proposed layout for medium scale dairy farm

The Figure 18 shows the layout for medium scale dairy farm which consists of basic structural buildings and processing facilities.

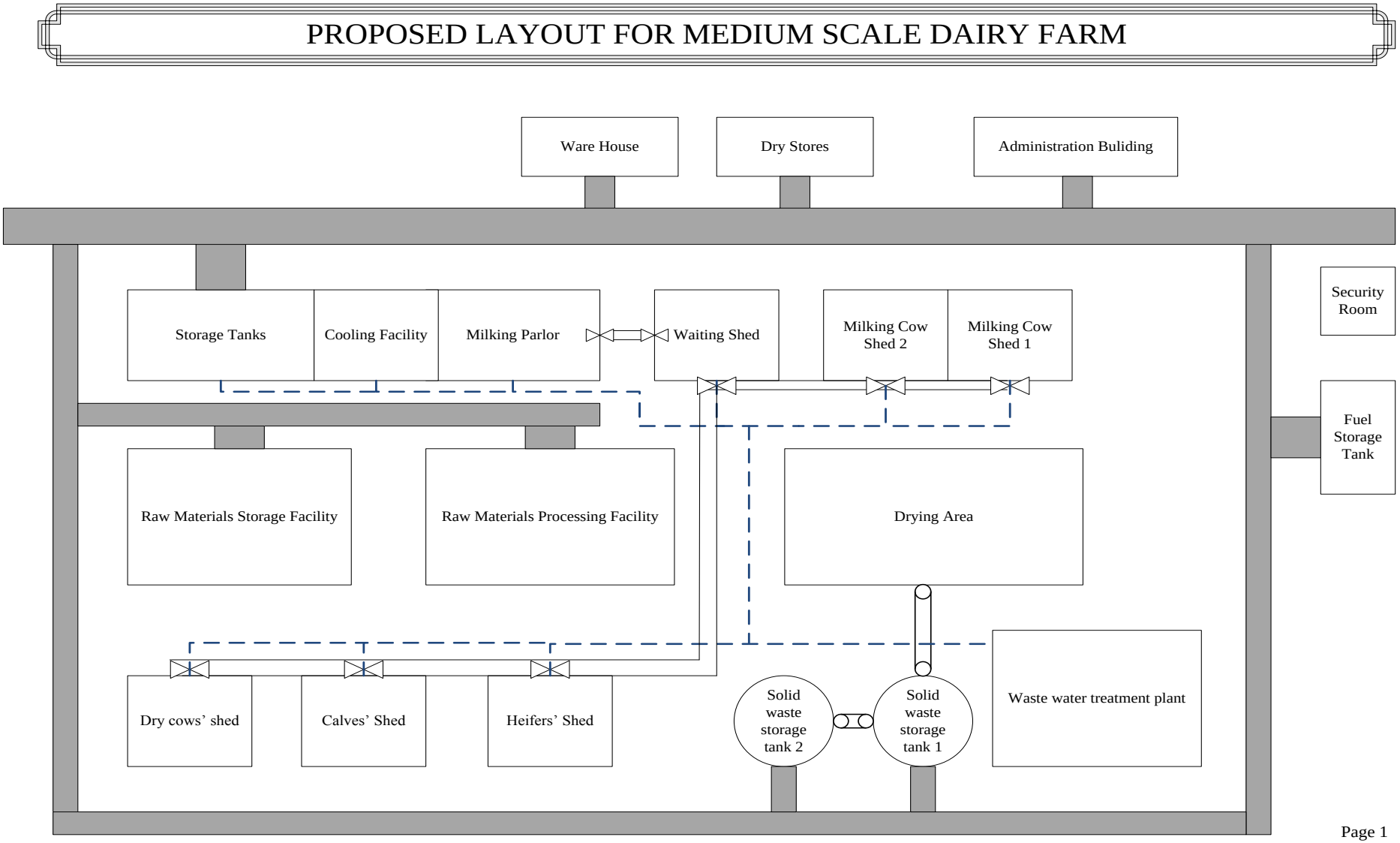

Figure 18: Proposed layout for medium scale dairy farm

Nomenclature

Symbol	Description
ρ_{milk}	Density of cow milk [kgm^{-3}]
V	Volumetric flow rate of milk [m^3s^{-1}]
c_1	Specific heat capacity of cow milk [$Jkg^{-1o}C^{-1}$]
N	Number of milking cows in the farm[-]
c_2	Specific heat capacity of water [$Jkg^{-1o}C^{-1}$]
$\dot{m}_1$	Mass flow rate of water at room temperature [kgs^{-1}]
$\dot{m}_1$	Mass flow rate of ice water [kgs^{-1}]
Q	Amount of heat transferred [J]
θ	Change of temperature [^oC]
$\dot{Q}$	Power absorbed or transferred [W]
U_k	Overall heat transfer coefficient [$Wm^{-2}K^{-1}$]
A_j	Surface area of heat transfer [m^2]
T_{out}	Outside temperature of storage tank [^oC]
T_{in}	Inside temperature of storage tank [^oC]
α_{liquid}	Heat transfer coefficient of liquid [$Wm^{-2}K^{-1}$]
d	Thicknesses of stainless steel plates and insulation material [m]
λ	Heat transfer coefficients of steel and insulation material (polyurethane foam) [$Wm^{-1}K^{-1}$]
α_{air}	Heat transfer coefficient of air [$Wm^{-2}K^{-1}$]
Q_o	Heat loss of storage tank through walls [J]

Table 24: Nomenclature of symbols

Abbreviations

Abbreviation	Description
ECM	Energy Corrected Milk
IFCN	International Farm Comparison Network
FAO	Food and Agricultural Organization
IRR	Internal Rate of Return
HTST	High Temperature Short Time
HHST	Higher Heat Shorter Time
UHT	Ultra High Temperature
LME	Liquid Milk Equivalent
AFS	Australian Friesian and Sahiwal
CIS	Common wealth of Independent States

Table 25: Abbreviations

Appendices

Appendix 01: Farm Data

Farm / Industry Data

Name of the Farm/Industry: Farm Ruda

Address: Skola zemedelsky podnik Lany, Ruda

Production:

Raw materials	By products	Final products	Wastages
Corn silage	Heifers for fattening	Milk ▪ Dairy (95%) ▪ Calves (5%)	Spoiled feed (5% - 10% of supply)
Alfalfa silage		Manure as fertilizer ▪ Liquid manure ▪ Dry manuer	Water
Whey straw			
Alfalfa hay			
Concentration mix ▪ Soy bean ▪ Waste from brewery ▪ Brewery yeast ▪ Vitamin and mineral compounds ▪ Molasses ▪ Glycerol liquid ▪ Fat			

Table 26: Farm data - Production

Capacity:

Description	Value	Unit	Notes
Total No. of Animals	800	No.	
1) Lactating Adults	420	No.	
2) Calves	50	No.	
3) Heifers	30	No.	
4) Pregnant cows	170	No.	
5) Dry cows	120	No.	
Input of raw materials			
1) Corn silage	9705	kg/ day	
2) Alfalfa silage	12195	kg/ day	
3) Alfalfa hay	874	kg/ day	
4) Waste straw	210	kg/ day	
5) Concentration feed	4307	kg/ day	
6) Molasses	210	kg/ day	
7) Glycerol	261	kg/ day	
8) Grass hay	440	kg/ day	
9) Barley straw	490	kg/ day	
10) DCAB	25.5	kg/ day	
11) Minerals and Vitamins (A,D & E)	15	kg/ day	
Final products			
1) Milk for dairy industry	9000	liter / day	
2) Milk for calves	400	liter / day	
3) Dry manuer	130	MT / month	
Area			
1) Animal house	0.5	Hectares	
2) Other	1.5	Hectares	
3) All	2.0	Hectares	
Utilities consumption			
1) Electricity			
▪ Peak voltage		v	

	▪ Units consumption		kWh / month
2)	Water	1298	m^3 / month
3)	Detergents		
	▪ Acids	100	liter / month
	▪ Alkaline	100	liter / month
	▪ Pre dip	30	kg / month
	▪ Post dip	10	kg / month
4)	Fuel	9000	liter / month

Table 27: Farm data - Capacity

Machinery

1. Milking parlor

Type : Flat barn / Herring bone / Parallel / Swing / Walk through / Rotary / Other

No. of cubicles : 11 x 2

No. of milking times per day : 2 Time limits per milking : 12 hours

Machinery / Equipment	**Type**	**Capacity**	**Power consumption (kW)**
Vacuum pump	VP 78	2500 liter/min 50 kPa	7.5
Pumping sub stations			
1) Pump 1			
2) Pump 2			
3) Pump 3			
Pulsator / s			
Disinfection unit			

Table 28: Farm machinery - Milking parlor

2. Cooling and Storage facilities

Cooling agent / s : Ice water

Refrigerant type / s : R134a

Heat exchangers

Type	Capacity	Cooling agent	Refrigerant
Cooling bath	-	Ice water	R134a

Table 29: Farm machinery - Heat exchangers

Time consumption

Type	Flow rate (liter/sec)	Temperature drop (ºC)	Time consumption (min)
Cooling bath	-	35 ºC to 4 ºC	100

Table 30: Farm machinery - Time consumption for cooling

Storage tanks

Tank	Capacity (m^3)	Maintained Temperature (ºC)	Storage time
Tank 1	6.5	4	Maximum 20 hours
Tank 2	6.5	4	Maximum 20 hours

Table 31: Farm machinery - Storage tanks

3. Other Machineries

Machinery	Type/s	Capacity	Fuel
Tractors	ZETOR 9541		Diesel
	ZETOR 7011		Diesel
Loaders			
• Loader for hay & waste	ZETOR 7441	0.53 m^3	Diesel
• Loader for silage	MANITOU LT 753		Diesel
Other			
• Mixture wagon	SETTER Horizontal Screw Conveyor	13 m^3	Diesel
• Transportation Loader	JD 7810 + PRONAR	12,130 kg	Diesel
• Milk wagon with pasteurizer	VM – 14 – 180	180 liter	Electricity

Table 32: Farm machinery - Other machineries

Note: 9 m^3 spare wagon in case of breakdown

Employment

Description	Value	Unit	Notes
Employees			
1) Caring animals	5	No.	
2) Production	8	No.	
3) Security	3	No.	
4) Administration	2	No.	
Employment			
1) No. of working hours	114	Hours/ day	
2) No. of working days	300	Days/ annum	

Table 33: Farm data - Employment

Appendix 02: Feeding Data

Feeding Data

Material	Animal Type and Average Consumption per day (kg)					Total (kg)
	Lactating Adults	Heifers	Pregnant cows	Dry cows	Calves	
Corn Silage	16.0	2.5	12.0	6.0	3.0	9705
Alfalfa Silage	20.0	14.0	10.0	10.0	9.5	12195
Alfalfa Hay	0.5 – 2.0	1.0	2.0	–	–	874
Waste Straw	0.5	–	–	–	–	210
Concentration Feed*	9.0	–	2.6	–	1.7	4307
Molasses	0.5	–	–	–	–	210
Glycerol	0.5	–	0.3	–	–	261
Grass Hay	–	1.0	–	3.0	1.0	440
Barley Straw	–	1.5	0.5	3.0	–	490
DCAB**	–	–	0.15	–	–	25.5
Mineral (Mg) and Vitamin (A,D & E)	–	0.1	–	0.1	–	15

Table 34: Feeding data

**DCAB – Dietary Cation Anion Balance

*Concentration Feed – Mixture of healthy nutrients (Rape, Soy bean extract, Whey & Barley, Feed fat, Waste from brewery processing, Vitamin and mineral compounds)

Feeding Machinery

Machinery	Type	Capacity	Notes
Tractors			
1) Wagon with mixture	Zetor 9541 (Mixture: Setter Horizontal screw conveyor)	13 m^3	Spare wagon with capacity of 9 m^3
2) Wagon without mixture	Zetor 7011 (Nkvs conveyor)	3 m^3	
Loaders			
1) Loader for hay and waste	Zetor 7441 (FL (HUMPOLEL))	0.53 m^3	
2) Loader for silage	MANITOU (LT 753)		
Conveyors			
1) Screw conveyor			
Other			
1) Transportation Loader	JD 7810 (Tractor engine) + PRONAR	12,130 kg	
2) Milk wagon with pasteurizer	VM – 14 – 180	180 liter	Feeding for calves

Table 35: Feeding machinery

Appendix 03: Milkers' Time Consumption

No. of workers : 03 No. of helpers : 02

Sequence	Activity of milker	Unit	Time (s)					Average time per cow (s)
			1	2	3	4	5	
1.	Lead cows for waiting shed	100 cows	690	900	760	-	-	8
2.	Entering from gate no.1 to waiting area	11 cows	90	95	72	104	98	8
3.	Entering from gate no.2 to milking parlor	11 cows	45	60	140	56	48	5
4.	Check sample and pre dip of teats	1 cow	10	8	8	7	6	8
5.	Wipe the udder with wet cloth	1 cow	5	5	6	8	5	6
6.	Fix cluster	1 cow	12	8	7	9	7	9
7.	Getting milk (not human activity)	1 cow	240	220	310	280	320	275
8.	Remove cluster	1 cow	AM	AM	8	AM	10	4
9.	Post dip of teats	1 cow	3	4	4	6	5	4
10.	Exit of cows	11 cows	52	63	65	72	54	6
	Total average time per cow							**333**

Table 36: Milkers' time consumption

AM : Automated process when the flow rate is less than 0.3 liter/min

Appendix 04: Daily Activities in the Farm

Activity	Hour of the day																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Feeding																								
1) Feed preparation for milking cows									x	x	x										x	x	x	
2) Feed distribution for milking cows						x	x	x										x	x	x				
Milking																								
1) Lead cows for waiting shed					x	x	x	x									x	x	x	x				
2) Enter the cows to milking parlor					x	x	x	x									x	x	x	x				
3) Check sample & pre dip of teats					x	x	x	x									x	x	x	x				
4) Wipe the udder with wet cloth					x	x	x	x									x	x	x	x				
5) Fix cluster					x	x	x	x									x	x	x	x				
6) Getting milk (not human activity)					x	x	x	x									x	x	x	x				
7) Remove cluster					x	x	x	x									x	x	x	x				
8) Post dip of teats					x	x	x	x									x	x	x	x				
9) Exit of cows					x	x	x	x									x	x	x	x				
Milk transportation																						x	x	
Waste management																								
1) Remove manure in cow sheds						x	x	x	x															
2) Wash out the drainage system						x	x	x	x															
3) Clean drinking water troughs																		x	x	x	x			
Caring other animals																								
1) Feeding calves									x	x											x	x		
2) Feeding heifers and dry cows											x	x	x								x	x	x	
3) Immunition & other treatments									x	x	x													

Table 37: Daily activities in the farm

Appendix 05: Capacities of milking parlors

Type	Number of milking stalls	Number of employees	Capacity (Cows / hour)
Side by side	2 x 3	1	32
	2 x 4	1	42
	2 x 5	1	55
	2 x 6	1	65
	2 x 7	1 – 2	74
	2 x 8	1 – 2	84
	2 x 9	1 – 2	93
	2 x 10	2	103
	2 x 12	2	117
	2 x 14	2	132
	2 x 16	2 – 3	150
	2 x 18	3	168
	2 x 20	3	185
Swing over	2 x 8	1 – 2	58
	2 x 10	2	72
	2 x 12	2	82
	2 x 14	2	92
	2 x 15	2 – 3	98
	2 x 16	2 – 3	105
	2 x 18	3	117
	2 x 20	3	129
	2 x24	3 – 4	150
	2 x28	4	168
Rotary milking parlor (Herringbone)	16	1	85
	18	1	100
	20	2	110
	22	2	120
	24	2	130
	28	2	140

	32	3	160
	36	3	180
	40	3	200
Rotary milking parlor (Parallel)	24	2	140
	28	2	150
	32	3	170
	36	3	190
	40	3	210
	50	3	250
	60	4	300
	72	4	350
	80	4	380
Auto tandem milking parlor	2 x 2	1	30
	2 x 3	1	44
	2 x 4	1 – 2	56
	2 x 5	2	73
	2 x 6	2	86

Table 38: Capacities of milking parlors

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