IMPROVING RESOURCE EFFICIENCY IN AN ICE CREAM FACTORY BASED ON MATERIAL FLOW COST ACCOUNTING METHOD

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FACULTY OF SCIENCE
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KUALA LUMPUR

2017

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DISSERTATION SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF TECHNOLOGY (ENVIRONMENTAL MANAGEMENT)

INSTITUTE OF BIOLOGICAL SCIENCES
FACULTY OF SCIENCE
UNIVERSITY OF MALAYA
KUALA LUMPUR

2017

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ABSTRACT

Due to the anthropogenic activities for the last 300 years, the earth has had so many changes. Human's first conflict with nature started after the industrial revolution in 18th centuries, when factories were being built one after another. Among all these industries, food industry like many others generate wastes but the attention to this industry has always been less as the waste characteristics is non-hazardous and biodegradable. The main challenges for food industry when it comes to waste are: packaging, processing wastes and their influence over municipal solid waste. For waste reduction, there has been many tools and approaches in which Material Flow Cost Accounting (MFCA) is the latest. MFCA was applied for the first time in Malaysia in an SME and an Ice Cream factory in Ipoh. Based on the MFCA approach, one product with highest amount of production was picked. Next step was to study the product's process flow, data collection, data analysis with STAN software and countermeasure to reduce the cost and increase the profit. The result was interesting as waste generation regardless of its measurement unit becomes more expensive as the process moves forward. Therefore, after identifying the source of waste, the main efforts was to reduce waste and costs at the later stages. Even though the cost reduction might not be significant but by considering the number of SMEs in Malaysia, even small amount of saving from wastes could have a positive impact on country's economy and environment.

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ABSTRAK

Akibat aktiviti antropogenik yang berlaku sejak 300 tahun yang lepas, bumi telah melalui banyak perubahan. Konflik pertama manusia dengan alam semula jadi bermula selepas revolusi perindustrian pada abad ke-18 iaitu apabila kilang telah dibina satu demi satu. Di kebanyakkan industri makanan terutamanya yang menjana sisa mendapat perhatian kerana cirinya yang tidak membahayakan serta mesra alam. Cabaran utama bagi industri makanan yang menjana sisa ialah: pembungkusan, pemprosesan sisa dan pengaruh terhadap sisa pepejal perbandaran. Dari segi pengurangan sisa, pendekatan terbaru dan terdekat yang digunakan ialah Kos Aliran Bahan Perakaunan (MFCA). MFCA telah digunakan buat kali pertama di Malaysia dalam industri kecil dan kilang Ais Krim di Negeri Ipoh. Berdasarkan pendekatan MFCA, satu produk dengan nilai tertinggi dalam pengeluaran telah dipilih. Langkah seterusnya adalah untuk mengkaji aliran proses produk, pengumpulan data, analisis data menggunakan perisian STAN serta balas untuk mengurangkan kos dan meningkatkan hasil keuntungan. Keputusan yang diperoleh menunjukkan bahawa penjanaan sisa tanpa unit adalah lebih mahal di peringkat terakhir proses. Oleh sebab itu, setelah mengenal pasti sumber sisa, langkah utama adalah bagi mengurangkan sisa dan kos pada peringkat yang seterusnya. Walaupun pengurangan kos mungkin tidak signifikan, tetapi setelah mempertimbangkan jumlah kilang di bawah industri kecil di Malaysia, maka penjimatan yang minimum daripada sisa boleh memberi kesan positif terhadap ekonomi negara dan alam sekitar.

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ACKNOWLEDGEMENT

First and foremost, I wish to thank God for being with me throughout the entire journey in completing my dissertation successfully. My heartfelt gratitude to my supervisors Dr. Noor Zalina Binti Mahmood and Dr. Abdul Halim Bin Sulaiman, for their guidance and support. My gratitude towards my parents, family and friends who were always there to support without fail in completing my project. My appreciation towards those who guided me in providing fruitful information and knowledge in the field of my research.

Special thanks to my lecturers. MTech mates, ISB, IPS, UM and the Dean of the Institute of Postgraduate Studies and Research for the funding of this study. It wouldn't have been completed despite the challenges faced without all of them.

My sincere appreciations to my dear friends Mehdi Almasi and Theepa for their kind assistance in preparation of this dissertation and for being very patient with me during this time. And finally, I would like to dedicate this dissertation to my beloved nieces Maryam and Sophie and my young nephews Youssef and Abbas who I wish them to grow in communities with wise consumption, greener practices and cleaner earth. As wise men have always said that we have not inherited earth from our ancestors but have borrowed it from our children. I sincerely hope this humble dissertation would be a stepping stone for a better future for everyone on this planet.

THANK YOU

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CHAPTER ONE: INTRODUCTION

1. Introduction

Due to the anthropogenic activities for the last 300 years, the earth has had so many changes. Human has invented so many things to make his life easier and to satisfy his ego. However, not all human's innovations have been sustainable and in favour of the environment. Human's first conflict with nature started after the industrial revolution in 18th centuries, when factories were being built one after another. The economy growth was rapid and the hunger for consumption and production was unlashed and that has caused so many disturbance and stress to the ecosystem due to the high volume of contaminants emission (Eco-Issues, 2011). Ever since, human tried to mitigate this issue which in many ways has direct relationship with its economy. Even United Nation Environment Program (UNEP) has established the Sustainable Consumption and Production (SCP) Branch with its integrated life-cycle approach towards achieving more sustainable consumption and production patterns (UNEP Sustainable Consumption, 1998). Economic crisis in 2008 could be considered as a turning point for the sixth wave of innovation (resource efficiency) as it has led many industries to focus on another product (negative product or waste) in their processes (Moody and Nogrady, 2010).

Food industries like many others generate wastes but the attention to this industry has always been less as the waste characteristics is non-hazardous and biodegradable (Darlington *et al*, 2008). This industry faces three main challenges when it comes to waste: packaging, processing wastes and their influence over municipal solid waste (DEFRA, 2009). However, the main focus of this research is to focus on the waste minimization which stands on top of the waste management hierarchy and in most cases is more efficient and economic than waste

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treatment. There are many different approaches to deal with waste minimization which among them, MFCA (Material Flow Cost Accounting) is the latest Environmental Management Accounting (EMA) tool which has already proved its effectiveness in many industries in Japan (Japanese Ministry of Economy, Trade and Industry, 2010) and since 2011 it has been published as a new ISO standard (ISO14051). The benefits of this new method in terms of cost reduction, increasing profit and decreasing environmental impacts are attracting more industries in different countries (MPC Creanova, 2010). In Malaysia, MFCA has already been implemented in several industries such as automobile parts and electrical cables manufactures. Unlike MFA (Material Flow Analysis) which its main focus is on materials and substances, MFCA also studies energy as well as costs for machine and labour. Even looking at wastes and costs associated with, is different as in MFCA waste is considered as negative product which means material and energy have been consumed to generate this product or waste (Jasch, 2009). Generated waste during the processes might have the same characteristics but the costs of wastes in latter processes are much higher as it is carrying all the costs (energy and labour) from the previous processes.

For the first time in Malaysia, MFCA is being implemented in an SME - a semi-automatic ice cream factory established in 1977 in Ipoh, Perak. The factory produces over 300 types of products, however, not all of them are produced daily and in this study, only "Chocolate Crunchy Cone" (CCC) product is considered which has the highest sales and productions among others. The factory already has a successful production and quality management program, but due to the market change (clients now have environmental consideration), wastewater treatment cost and more strict environmental laws, factory decided to implement the MFCA in addition to increase its profit by waste reduction and step forward towards sustainable development. Factory is generating three types of wastes which are wastewater

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(result of washing the equipment and its characteristics are not in compliance with the standard and therefore needs treatment), defect products (due to the machine malfunction or during the packaging process) and excessive packaging.

1.1. Scope and research objectives

The scope of this study will be on production of Chocolate Crunchy Cone (CCC) ice cream in the period of six months study on this specific product and the objectives of this research are:

1. To ascertain the process flow and establish material flow balance;
2. To identify the types and sources of waste/emission;
3. To calculate/convert the physical unit of waste/emission to monetary unit;
4. To propose improvement measures for selected ice cream product using MFCA approach;

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CHAPTER TWO: LITERATURE REVIEW

2. Food Industry in Malaysia

Malaysia's food industry is rich in terms of tropical and agricultural resources reflecting diverse cultures in Malaysian society consisting of Malay, Chinese and Indian (Abdul Manaf, 2008). The increasing awareness of consumer in nutrition value and food for healthcare has created demand for healthy processed fresh food, organic food and natural food flavours from seafood and plants. The Malaysian food market is becoming increasingly sophisticated and supplied by both local and imported products (Malaysia, 2008). The strong economic growth in the early 90's contributed towards major changes in consumer purchases and consumption patterns (Abdul Manaf, 2008).

In Malaysia, 10% of the manufacturing sector is food-processing industry which is dominated by small and medium scale companies. It has attracted to a total of RM1.972 billion in 69 projects which represents more than 80% of the total number of establishments in the processed food segment (Malaysia Food Business Directory (MFBD), 2007). Although the export performance of this sector has doubled over the last ten years (RM18 billion in 2015), Malaysia continues to be a net importer of food products with an annual import of more than RM36 billion in 2012 and processed foods of with an annual import of more than RM17.8 billion in 2015. The processing technology have widened the usage of local raw materials, broadening the range of products increasing the investment capacity in the food industry.

2.1. Sub - Sectors of Food Industry

The sub sectors involved in food and beverage industry include fish and fish products, livestock and livestock products, fruits and vegetables, and cocoa-based products (Porter ME,

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2008). The beverage segment covers the manufacture of soft drinks and mineral water (O'Brian, 2007). In the livestock sub-sector, Malaysia is self- sufficient in poultry, pork and eggs, but imports about 80% of its beef requirements. Among the dairy products produced are milk powder, sweetened condensed milk, pasteurized or sterilized liquid milk, ice cream, yoghurt and other fermented milk (Malaysia, 2008).

2.1.1. Livestock and Dairy

Poultry processing constitutes 60% of the meat processing industry (Sungkar, 2008). Although Malaysia is a net exporter of poultry meat, it is still a net importer of meat products, particularly beef and mutton. Among the dairy products produce dare milk powder, sweetened condensed milk, pasteurised or sterilized liquid milk, **ice cream**, yoghurt and other fermented milk (Porter ME, 2008).

2.1.2. Nature of Involvement by the Dairy Industry

Waste load in the dairy industry is largely as a result of milk products which are inadvertently lost to the sewer system (Malaysia, 2008). Subsequently, processors have had no need to monitor loads or volumes. The reduction of water and waste in a dairy processing plant requires the application of the best technology to achieve reduced product loss, reduced water usage, and reduced ingredient loss. This is only true when the dairy industry could discharge wastewater with little regard for treatment costs (Turban *et al.,* 2007).

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2.2. Overview of Dairy Processing Industry

The dairy industry is divided into two main areas:

1. The primary production of milk on farms—keeping of cows (and other animals such as goats, sheep etc.) for production of milk for human consumption;
2. The milk processing which is achieved by (a) heat treatment in ensuring the milk is safe for human consumption and extended quality, and (b) preparing a variety of dairy products in a semi-dehydrated or dehydrated form (e.g. butter, hard cheese and milk powders).

2.2.1. Introduction

The basic function of the dairy processing industry is the manufacture of foods based on milk products (Envirowise, 2002). There are 20 basic types of milk products manufactured, such as fruit juices, produced by the industry. Total milk production has increased by 32 percent. Many plants engage in multiproduct production. In an effort, of establishing effluent limitation guidelines and standards of performance by the EPA, the dairy industry was subdivided into categories according to types of product manufactured (UNEP, 2000).

i) Standard Industrial Classification (SIC) Codes and Title - Group 202

2021 Creamery Butter

2022 Cheese, Natural and process

2023 Condensed and Evaporated Milk

2024 Ice Cream and Frozen Desserts

2026 Fluid Milk

ii) Subcategories for Effluent Guidelines

Receiving stations

Fluid products

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Cultured products

Butter

Cottage cheese and cultured cream cheese

Natural cheese and processed cheese

Ice Cream, novelties and other frozen desserts

Ice cream mix

Condensed milk

Dry milk

Condensed whey

Dry Whey

i) Industry 2021 - Creamery Butter

Includes establishments primarily engaged in manufacturing of creamery butter. Specific products are anhydrous milkfat, butter, creamery, and whey.

ii) Industry 2022 - Cheese, Natural and Processed

Comprises of producers that primarily manufacture natural cheese, processed cheese, cheese foods and cheese spreads. Specific products include cheese (except cottage cheese) and cheese spreads, pastes, and cheese like preparations.

iii) Industry 2023 - Condensed and Evaporated Milk

Industry includes establishments primarily engaged in manufacturing of condensed and evaporated milk and related products. Specific products include baby formula; concentrated, condensed, dried, evaporated, and powdered buttermilk, milk, whey, and etc.

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iv) Industry 2024 - Ice Cream and Frozen Desserts

This industry depends on the manufacture of ice cream and other frozen desserts. Specific products are custard, ice cream, ice milk, ices, and mellorine-type products.

v) Industry 2026 - Fluid Milk

Includes the processing and distribution of fluid milk, cream and related products (cottage cheese). Specific products include: buttermilk, cultured; cheese, cottage; milk and cream products; and yoghurt.

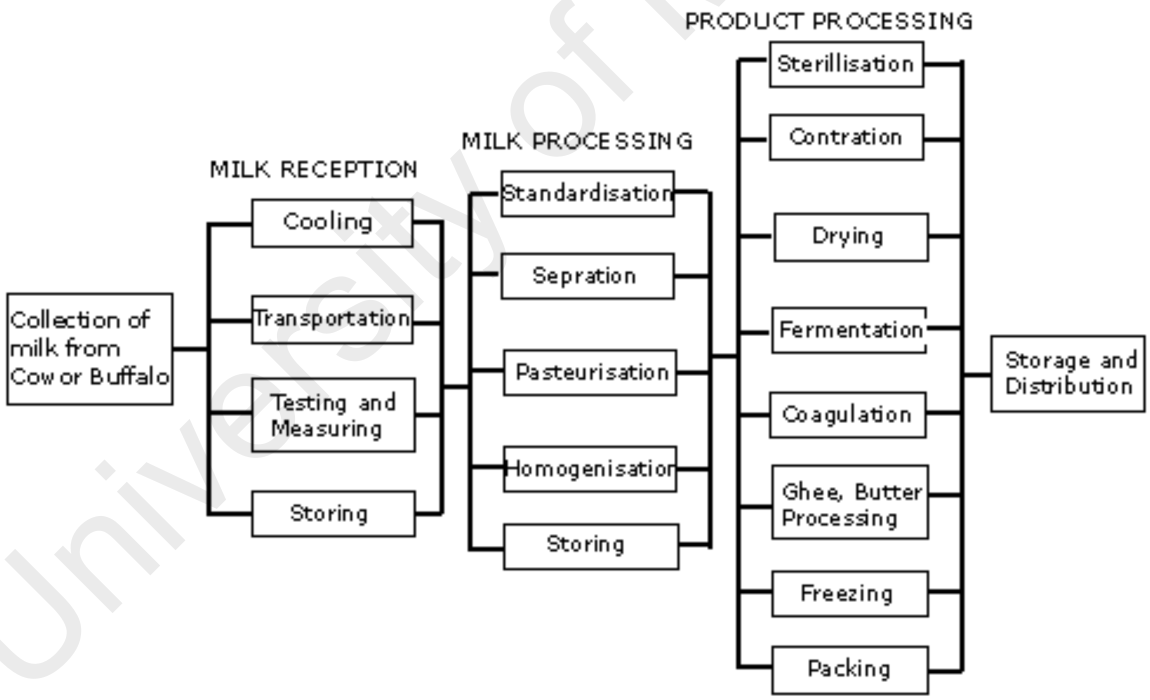

Figure 2.1: Diagram of Dairy Processing Plant (Source: Dagang Asia Net, 2011)

2.3.Trends in the Dairy Industry

Malaysia has one of the most sophisticated consumer markets in South East Asia. Unlike the other large Southeast Asian nations, e.g. Indonesia, Thailand and the Philippines, Malaysia

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has a nation-wide consumer base that encompasses both urban and provincial/rural areas (Ananda, 2008). Middle to upper income group of consumers comprise about 61% of the population or 14 million people. They are key targets for the full range of dairy products that are in market today (Chang, 2007).

2.3.1. Dairy Processing Plant Schemes

2.3.1.1 Introduction

This will provide an insight and review of the different operations involved in processing dairy commodities.

2.3.1.2. Processing Operations

In dairy products industry, a great variety of operations are encountered and can be considered as a chain of operations. This involves receiving and storing of raw materials, processing them into finished products, packaging and storing finished products, and a group of other ancillary operations such as heat transfer and cleaning (Abdul Manaf, 2008). Facilities for receiving and storing raw materials are fairly consistent throughout the industry with very few major modifications associated with changes of raw materials (Ananda, 2008). Under normal operations, with good housekeeping, receiving and storing raw materials do not constitute major sources of wastes (Chang, 2007).

They consist of a receiving area where bulk carriers can be attached to flexible lines for transfer of materials, and large refrigerated tanks for storage (Dierks, 2011). Wastes comes from leaks, spills and removal of unwanted materials during cleaning and sanitizing of equipment. However, initial operations of clarification, separation and pasteurization are

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common to most products (Dierks, 2011). Removal of suspended matter, cream, or milk are determined by using large centrifuges of special design (Chang, 2007).
The operation of clarification and separation are usually carried out in separate units (Malaysia, 2008). A single unit is required to discharge the sludge that could be sanitized easily. Some may also use inline filters to remove suspended matter (HDC, 2008).

Following clarification and separation process, the materials which are subjected for further processing within the plant are pasteurized (O' Brian, 2007). Pasteurization requires heating the material for a fairly long period of time in a vat pasteurization. For this purpose, heating is required at a high temperature within a short time (Dagang Asia Net, 2011). After the initial operations mentioned above, the processes and equipment become highly dependent on the product. Types of equipment encountered are tanks and vats for mixing ingredients and culturing products, enclosed high-pressure spray units, evaporators and various driers for removal of water, and freezer (Envirowise, 2002).

The finished products are packaged, cased and sent to storage for subsequent shipment (Janis, 2004). The product fill lines employed in dairy processing products industry are typical liquids and solids packing units, with only minor modifications to the products and containers. The storage temperature ranges from below zero to above freezing (O'Brian, 2007).

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2.4. Wastewater Characterization of Dairy Plant

2.4.1. Introduction

The quantity of this processing wastewater that is generated and its general quality (i.e., pollutant strength, nature of constituents) has both economic and environmental consequences with respect to its treatability and disposal (Dierks, 2011).

By considering that the wastewater contains substances and materials from the product (or loss of the product) therefore, the economics and the value of the wastewater would depend on the amount of product loss from the cost of treatment and processing operations of this waste material (MFBD, 2007). In another word, richer the wastewater is in terms of the product ingredients, the higher cost of treatment it would have. Therefore, the cost of treating the wastewater would depend on the specific characteristics of the pollutant in the wastewater. Other factors for the cost of wastewater treatment would be the daily volume of discharge and relative strength of the wastewater (Dierks, 2011).

If treated wastewater were to be discharged into a stream or river, an eutrophic condition would develop within the aquatic environment. This is due to the discharge of biodegradable and oxygen consuming compounds (Porter, 2008). If this situation was sustained for a sufficient amount of time, the ecological balance of the receiving stream, river or lake (i.e., aquatic microflora, plants and animals) would be affected (Evans, 2003). Moreover, continued depletion-of the oxygen in these water systems would result in development of unsightly scum and odours (Malaysia, 2008).

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2.4.2. Dairy Industry Wastewater-Pollution/pollutant

The major pollutant of dairy plant is organic material. The organic material is decomposed by micro-organisms in the water, when dumped untreated into a stream or river (Evans, 2003). The micro-organisms consume oxygen in the water by breaking down the organic pollution and this will degrade the water quality by depleting its oxygen content (Janis, 2004). Oxygen depletion leads to impact towards fish, plants and other aquatic animals which needs dissolved oxygen to survive. When oxygen in the water body is used up, the decay of organic matter continues without oxygen and that evidently would lead to noxious gases such as hydrogen sulphide and methane are produced (Chang, 2007).

Another type of major pollutant produced in dairy plant is suspended solid waste. This include constituents such as coagulated milk, particles of cheese curd, and in ice cream plants, pieces of fruits and nuts (O' Brian, 2007). The measurement of this pollutant is called "total suspended solids," or TSS. These TTS discharge their colours and cause the water to become slurry. In addition to that, TTS and their organic characteristics would settle on the bottom of the stream and impair photosynthesis in aquatic plants. As dairy wastes do, the bottom deposits become sludge beds that can further deplete the water's oxygen content (Porter, 2008). This gives off gases that are toxic to aquatic life and cause odour problems, as the sludge decomposes (Malaysian Institute of Economic Research, 2005).

Suspended solids in water from streams used by the dairy industry can interrupt with many industrial processes. They cause foaming in boilers, damage equipment, and impose high purification costs on industries that need clean water (Cole, 2008). An example of it would

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be the pharmaceutical industry which would require high amount of clean water to make their products (Malaysia, 2008).

Raw wastes from dairy plants contain excessive amounts of organic materials and suspended solids. These wastes must be treated before they are discharged into a water body and the major dairy industry water pollutants such as organic material and suspended solids can be treated effectively (Turban *et al.*, 2007).

Other identified pollutants in dairy plant wastes are phosphorus, nitrogen, chlorides, and heat. In general, treating dairy wastes to reduce the amount of organic material and suspended solids will keep other pollutants at satisfactory levels. In some cases, some of the minor pollutants may need special treatment (Nguyen *et al.,* 2004). Another consideration is the acid or alkali content of liquid wastes. The pH of many individual wastes within a dairy plant fall outside the range for direct steam discharge. Therefore, the wastes are neutralized when they are mixed within a plant or during the treatment process and pH can be easily adjusted (Cole, 2008).

Wastes from most dairy plants can be successfully treated by municipal treatment plants and pose no threat to the municipal plants. However, in some situations, a by-product cheese-manufacturing whey may create problems in some municipal treatment plants. Typically, whey creates problem when it is a large portion of the flow to a treatment plant which is greater than 10%. A pre-treatment may be required in this situation by the municipality (Ananda, 2008).

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2.4.3. Environmental Impacts of Dairy Processing Plant/ Dairy products

The environmental impacts associated with dairy processing activities are the high consumption of water, discharge of effluent with high organic loads and consumption of energy. Noise, odour and solid wastes may also be other contributing factors as well (Sungkar, 2008). Dairy processing requires large amount of fresh water which is used primarily for cleaning process equipment and work areas to maintain hygiene standards (Turban *et al.,* 2007).

The major environmental problem caused by dairy processing is the discharge of large quantities of liquid effluent (Sungkar, 2008). Dairy processing effluents generally exhibit the following properties such as:

a) high organic load due to presence of milk components;

b) fluctuations in pH due to presence of acidic cleaning agents and other chemicals;

c) high levels of nitrogen and phosphorus;

d) fluctuations in temperature.

Source: (Abdul Manaf, 2008)

If whey from the cheese-making process is not used as a by-product and discharged along with other wastewaters, the organic load is increased, resulting in environmental problems. Milk is a complex fluid that consists of water, milk fat, few numbers of proteins (both in suspension and solution), milk sugar (lactose) and mineral salts (OECD, 2008).

Dairy products, depending on the nature, type of product and method of manufacturing, may also contain sugar, salts (e.g. sodium chloride), flavours, emulsifiers and stabilizers in the milk constituents (UNIDO, 2008).

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For some municipalities, the effluent from local dairy processing plants represents a significant load on sewage treatment plants. In extreme cases, the organic load of waste milk solids entering a sewage system may exceed that of the township's domestic waste, overloading the system (OECD, 2008). In rural areas, dairy processing effluent may be irrigated to land which could affect soil structure and salinity. In some locations, effluent may be discharged directly into water bodies (HDC, 2008).

Dairy products such as milk, cream and yogurt are typically packed in plastic-lined paperboard cartons, plastic bottles and cups, plastic bags or reusable glass bottles. Other products, such as butter and cheese, are wrapped in foil, plastic film or small plastic containers. Milk powders are packed in multi-layer kraft paper sacs or tinned steel cans, and some other products, such as condensed milks, are packed in cans. The packaging materials are usually discarded and improper packaging could be returned for reprocessing (OECD, 2008).

Emissions to air from dairy processing plants are caused by high levels of energy consumption necessary for production. Steam, used for heat treatment processes (pasteurisation, sterilisation, drying etc.) is produced in on-site boilers. Electricity used for cooling and equipment operation is purchased from the grid (UNIDO, 2008).

Air pollutants, including oxides of nitrogen, sulphur and suspended particulate matter, are formed from the combustion of fossil fuels, which are used to produce both these energy sources. In addition, discharges of milk powder from the exhausts of spray drying equipment can be deposited on surrounding surfaces (Envirowise, 2002).

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The use of steam injection for heat treatment of milk and creation of reduced pressure in evaporation processes causes high noise levels. A substantial traffic load within the immediate vicinity of a dairy plant is generally unavoidable due to the regular delivery of milk (which may be on a 24-hour basis) (Dess, *et al.,* 2005). This include deliveries of packaging and regular shipment of products. Noise problems should be taken into consideration in determining the plant location (Evans, 2003).

Hazardous wastes consist of oily sludge from gearboxes of moving machines, laboratory waste, cooling agents, oily paper filters, batteries, paint cans and etc (OECD, 2008). At present, in Western Europe, some of these materials are collected by waste companies, while some are sent for incineration. The remaining would be easily disposed (Dagang Asia Net, 2011).

2.5. Water Consumption in Dairy Processing Industry

Water is principally used for cleaning equipment and work areas to maintain hygienic conditions. Rates of water consumption vary greatly depending on the scale of the plant, age and type of processing, either batch or continuous processes. A typical range for water consumption in reasonably efficient plants is 1.3 to 2.5 litres water/kg of milk intake (Dess, 2005).

In most parts of the world, the cost of water is increasing as the true environmental costs of its supply are taken into consideration (Malaysia, 2008). Water is an increasing commodity and its efficient use is becoming more important (O' Brian, 2007). Strategies in reducing water consumption may include technological solutions or equipment upgrade. Some of the key strategies in reducing water consumption are listed below and the use of these techniques would indicate best practice for the industry. Therefore, water consumption can be reduced

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to 0.8–1.0 litres water/kg of milk intake (Dierks, 2011). According to Porter (2008), some of the water consumption reduction strategies are:

a) using continuous processes to reduce frequency of cleaning; An example of it would be a container which constantly gets filled with mixture of ingredients for ice cream or any other product. So instead of having a repetitive production for 12 hours and then washing, it would be continuous production of 24 hours and one round of washing so it would reduce the water consumption.
b) using automated cleaning-in-place (CIP) systems for control and optimization of water use; This technique has been around for 50 years and include the use of mixture of chemical, heat and water to clean machinery, vessels or pipe without dismantling plant.
c) installing fixtures that control the flow of water for manual cleaning processes;
d) using high pressure rather than high volume for cleaning surfaces; This strategy has been used in carwashes for a long time. Even though it significantly reduces the water consumption but it requires equipment such as compressor which could end up in more energy consumption.
e) installing meters on heavy equipment to monitor consumption;
f) using compressed air instead of water where appropriate; This technique can only be used for equipment which could be cleaned by air and do not require water for this purpose. Similar to high pressure rather than high volume water, this technique also requires electricity and evidently would result in higher energy consumption.
g) reporting and fix leaks promptly; Perhaps this is the oldest approach in reducing the water consumption and it is a continuous effort for constant checking and fixing but

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the outcome is less water consumption, less water bill and higher environmental practice.

2.5.1. Effluent discharge in dairy processing plant

Most water consumed at dairy plants becomes effluent. Dairy plant effluent is treated on site and then discharged to municipal sewerage systems. Dairy processing effluent contains milk and milk products which have been lost from the process, as well as detergents. Milk loss can be as high as 3 to 4%, with the main source being residues which remain on the internal surfaces of vessels and pipes or accidental spills during tank activities (Porter, 2008).

A typical figure for the COD load in dairy plant effluent is about 8 kg/m^3 milk intake (Turban *et al.,* 2007). Strategies in reducing the organic load of dairy effluents focus on minimising the amount of product lost to the effluent stream. Based on SME Annual Report, 2007, some strategies to reduce the organic load in the effluent are listed below:

a) ensuring the vessels and pipes are drained completely and using pipes and plugs to remove product residues before cleaning; Some of the approach would be to design the pipes from one tank to another in a way that the gravity helps maximum drainage of the fluid containing organics.
b) using level controls and automatic shut-off systems to avoid spills from vessels and tanker emptying;
c) collecting spills of solid materials (cheese curd and powders) for reprocessing, instead of washing it down; Some of the spilled materials and ingredients under the correct circumstance can get back to the production line which means less organic as waste.
d) fitting drains with screens and/or traps to prevent solid materials entering the effluent system; Some filter layers can capture and hold the solid organic from entering the effluent.

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e) installing in-line optical sensors and diverters to distinguish between product and water;
f) installing and maintaining level controls and automatic shut-off systems on tanks;
g) using dry cleaning techniques where possible, by scraping vessels before cleaning or pre-cleaning using air guns;
h) using starch plugs or pigs to recover product from pipes.

2.6. Overview of Dairy Processing Plant Worldwide

Dairy processing occurs world-wide. The structure however, varies from one country to another. In less developed countries, milk is generally sold to the public, directly. In major milk producing countries most milk is sold on a wholesale basis (Dess *et al.,* 2005). In Ireland and Australia, for example, many of the large-scale processors are owned by the farmers as co-operatives. In the United States, individual contracts are agreed between farmers and processors (Laudon, Laudon (2007) *Management Information Systems*. McGraw-Hill, New York).

Dairy industries in major dairy producing countries have undergone rationalisation, with a trend towards less but larger plants operated by fewer people (Janiz, 2004). As a result, in the United States, Europe, Australia and New Zealand most dairy processing plants are quite large. Plants producing market milk and products with short life span, such as yoghurts, creams and soft cheeses, tend to be located on the fringe of urban centres close to consumer markets (Cole, 2008) while plants manufacturing items with longer life span, such as butter, milk powders, cheese and whey powders, tend to be located in rural areas closer to the milk supply. The general tendency world-wide, is towards the large processing plants specialising in a limited range of products (Nguyen *et al.,* 2004). However, in Eastern Europe for example,

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due to supply-driven concept of the market, it is very common for 'city' processing plants to be a large multi-product plant producing a wide range of products (Evans, 2003).

This general trend has provided companies with the opportunity to acquire bigger, automated and more efficient equipment. This development has increased the environmental loadings in some areas for long-distance distribution (Nguyen *et al.,* 2004).

In the past decade, basic dairy processes have changed a little. Specialised processes such as ultrafiltration (UF), and modern drying processes, have increased the opportunity for the recovery of milk solids that were formerly discharged (OECD, 2008). In addition, all processes have become much more energy efficient and the use of electronic control systems has allowed improved processing and cost savings (Ananda, 2008).

2.7. Ice Cream Production

Ice cream production involves traditional chemical engineering, product design, and multiscale analysis. The components of this design are briefly summarized below, followed by an executive summary of the results generated for this design (Functions of Gums in Food Systems, 2005).

2.7.1. Science of Ice Cream

Ice cream is a very common and loved dessert and snack around the world. Eating ice cream is perceived as a pleasure and a luxury treat. However, the pleasure of eating ice cream requires a creamy and smooth product throughout the entire life cycle (Malaysia, 2008). The recipe and processing parameters influence the product quality as experienced by the consumers. During transportation and storage of ice cream, from the factory via shop to the consumer, there is a high risk of quality loss of product (Porter, 2008). Ice cream is a complex

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system which contains a gas (air) dispersed as small cells in a partially frozen continuous phase. In this phase, fat is used as an inner phase in an emulsion, where the milk solids and stabilizers are in a colloidal solution. The sugar and salts form a true solution (Ramli, 2006).

There are total of three categories of ingredients in the ice cream mix which include dairy, sweeteners, and additives. Milk, cream, and non-fat milk solids make up the dairy portion of ice cream while Sucrose or Splenda® is used to sweeten the mix. Stabilizers and emulsifiers are mixed to give the ice cream the desired feel (Ramli, 2006). Also present in finished ice cream is air. Standard ice cream contains an equal volume of mix and air, or an over-run of 100%. Premium ice cream, however, has an over-run of only 80%. This to give a rich creamy texture (OECD, 2008). Milk is a colloidal suspension of water, fat, and milk solids in which fat particles in suspension range in size from 0.8 to 20 µm. Another present substance in milk is the sugar lactose at a concentration of about 4.9%. In lactose free ice creams, the milk is treated with enzyme lactase, which breaks the lactose down into simpler sugars glucose and galactose (Sungkar, 2008).

Regular table sugar, or sucrose, is used as a sweetener in ice cream mixes except low carb ice cream. Splenda®, or sucralose, is used to sweeten the low carb ice cream because it is indigestible but sweetens the mix (Malaysia, 2008). Stabilizers and emulsifiers are essential in the production of ice cream as these two components help to give the ice cream smooth body to improve the overall texture of the ice cream. Stabilizers work by reducing the amount of free water in the ice cream mixture. This affects the growth of ice crystal during storage which also provides resistance to melting which goes through two mechanisms, depending on the type of gum (OECD, 2008).

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Charged gums, including carrageenan, help to reduce the amount of free water by introducing partial charges into the mixture. These charges interact with the partial charges of water and help to restrict the movement of water molecules within the mixture (Porter, 2008). Branched gums, including guar gum, provide the same ability to reduce free water within the system, by introducing many branched side chains into the mixture (Sungkar, 2008). Both types of gums limit the amount of hydrogen bonding, thereby giving the ice cream the desired properties.

Likewise, emulsifiers help to reduce fat globule coalescence by decreasing the interfacial tension between fat and matrix within the ice cream mixture (MFBD, 2007). Common types of stabilizers used for ice cream production include guar gum, carrageenan and gelatine (Turban *et al.,* 2007). Mono and diglycerides are the most common emulsifying agents. Addition of stabilizers and emulsifiers are essential for ice cream base mixes lower in fat content. This is the result of milk and milk proteins containing natural stabilizing and emulsifying materials. Therefore, premium ice cream will need minimal amounts, if any, of additional stabilizers or emulsifiers (Malaysian Institute of Economic Research, 2005).

As water begins to freeze in the mix, the concentration of dissolved solids in the liquid phase increases due to freezing point depression. Good mixing is essential for finished ice cream in terms of taste and texture (Ananda, 2008). Large fat globules increase the viscosity of mix beyond what is desirable. Typical ice cream viscosities range from 50-300 cP. The viscosities of low carb ice cream were found to be greater than that of regular or premium ice cream. It was thought that these high viscosities were the result of increased fat content as well as increased additive content (Abdul Manaf, 2008).

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2.7.2. Producing ice cream with a high overrun

Production of ice cream with high overrun is an interesting tool for cost saving. However, the perceived quality by the consumer must be kept in mind (Cole, 2008). The sensory attributes such as creaminess and smoothness as well as resistance towards shrinkage and melting cannot be compromised as these properties are very closely linked to consumer preferences (Dess *et al.,* 2005). Creaminess as well as melting resistance is related to the distribution of air cells in the product. A more uniform air cell distribution in the ice cream results in a creamier and slower melting ice cream. Emulsifiers like mono and diglycerides are well known for their positive influence (Sungkar, 2008).

2.7.3. The effects of emulsifiers

Production of ice cream with high overrun means, other things are being equal, the cell walls around the air cells are thinner and weaker. Therefore, it is at high risk of overrun in production of ice cream (MFBD, 2007). However, by choosing the right emulsifiers and stabilizers it is possible to manufacture an ice cream with high overrun which is still perceived as a high-quality ice cream. Emulsifiers are surface active ingredients due to their hydrophilic-lipophilic properties and they play an important role (Dagang Asia Net, 2011). Consequently, they place themselves in the interfacial layer between the fat/protein and water. The main functionality of emulsifiers in ice is to destabilize the fat globule membrane covering globules formed during homogenization of the ice cream mix (MFBD, 2007). During ageing, proteins covering the fat globule are replaced by emulsifiers. Therefore, agglomeration of the fat globules is facilitated. This is important for the formation of structure and air cell distribution during whipping and freezing process. Further, emulsifiers are important for the stability of the formed air cells such as strength of the air cell walls (Dierks, 2011).

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In short term, based on Source: HDC, 2008, the functionality of emulsifier in ice cream are

a) improved fat emulsification in the mix;
b) controlled fat agglomeration and coalescence;
c) facilitated air incorporation;
d) improved dryness on extrusion;
e) improved melting resistance;
f) improved heat-shock stability;
g) improved smoothness and creaminess.

2.7.4. Types of emulsifiers

Mono- and diglycerides of fatty acids (E471) are the most commonly used emulsifier in ice-cream. Mono- and diglycerides of fatty acids are produced by interesterification of glycerol and fat. The selection of fat determines the functional properties of emulsifier. The mono- and diglycerides can further be esterified with organic acids. For example, lactic acid is used for formation of E472b lactic acid esters of mono- and diglycerides of fatty acids, so called lactic acid esters (Dierks, 2011).

Compared to mono-and diglycerides, lactic acid esters are more hydrophilic. Lactic acid esters are not commonly used in ice cream production. However, it has been found that lactic acid ester has a great influence on foam stability and texture. Specifically, when it is used in combination with mono and diglycerides. This fact can be utilised in production of ice cream with high overrun (Dagang Asia Net, 2011).

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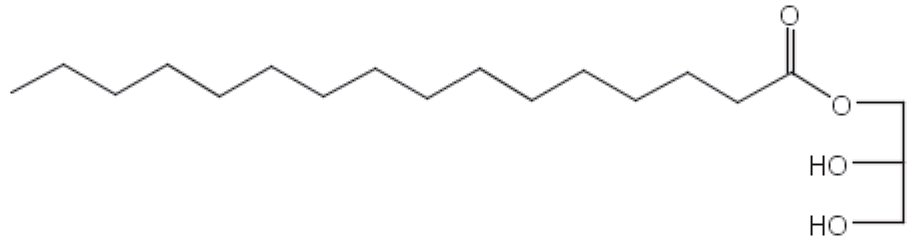

Figure 2.2: E471

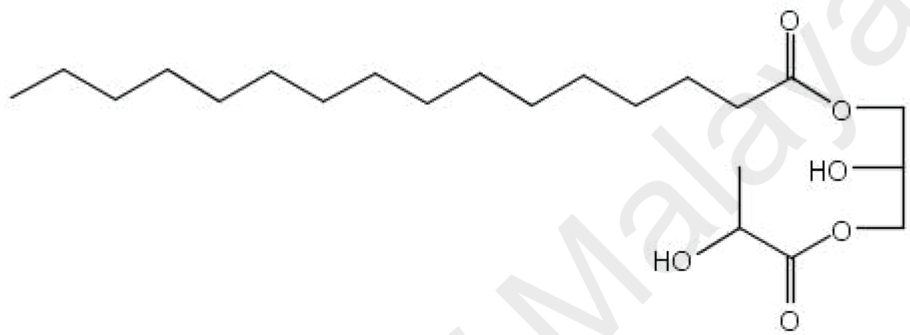

Figure 2.3: E472b

2.7.5. The effect of stabilizers in an ice cream with high overrun

The emulsifiers for high overrun in ice cream were used together with stabilizers. The stabilizers were hydrated and dispersed in water reducing the amount of free water in the ice cream mix. The stabilizers bind the water by means of hydrogen bonds and trap the water in a three-dimensional network reducing mobility of water resulting in an increased viscosity (Cole, 2008).

Base on (MFBD, 2007) study, the main functions of the stabilizers are to:

a) increase the mix viscosity
b) prevent whey separation (syneresis)
c) improve the whipping properties
d) improve the texture

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e) prevent ice crystal growth (during storage)

f) improve the melting resistance

g) regulate sensory properties

The options when choosing stabilizers were far greater than in the case of emulsifiers. Most countries allow the use of a wide range of stabilizers (OECD, 2008). The most commonly used stabilizers in ice cream according to Ananda, 2008 are guar gum (E412), locust bean, gum (E410), cellulose gum (E466), alginate (E401) and carrageenan (E407).

2.7.6. Manufacturing ice cream with 150 to 185% overrun

Palsgaard recently carried out a project with the aim of creating a solution for production of ice cream with overrun as high as 150 to 185% (Ananda, 2008). The quality in terms of sensory attributes, melt-down properties and storage stability should be comparable to standard ice cream. Ice creams with fat level from 6 to 10% were included in the trials (Dierkss, 2011). Vegetable fat was used as fat source and whey powder and/or skim milk powder was used as milk solid which is non- fat. The use of whey powder showed that the protein level was low in some of the trials (Abdul Manaf, 2008).

The ice cream was produced in Palsgaard's pilot plant by means of HTST unit combined with a continuous freezer (Chang, 2007). After hardening, the ice creams were transferred to a storage freezer at -18°C. For evaluation of the storage stability, heat-shock tests were carried out by increasing the temperature to -10°C for 4 days after which the ice creams were then transferred back into the storage freezer (Abdul Manaf, 2008).

2.7.7. The importance of air in ice-cream

Air is an important component in ice cream affecting the physical and sensory properties as well as the storage stability (Chang, 2007). Ice cream has around 100% overrun meaning that

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the air makes up 50% of the ice cream volume. The amount of air incorporated in the mix, influences the sensory attributes of the ice cream. If a lower amount of air is applied, the resulting ice cream is dense, heavy and colder. If a higher amount is used, the texture is lighter, creamier and warmer for eating (Dagang Asia Net, 2011).

2.8. Cleaner Production

Cleaner Production is defined as the continuous application of an integrated preventive environmental strategy applied to products, processes, and services to increase overall efficiency and reduce risks towards humans and environment. According to Malaysia, 2008, Cleaner production can be used in production processes, product development and design and service industries.

a) Production processes: Cleaner Production involves conservation of raw materials and energy, elimination of toxic raw materials, and reduction in quantities and toxicity of wastes and emissions.

b) Product development and design: Cleaner Production involves reduction of negative impacts throughout life cycle of the product: from raw material extraction to ultimate disposal.

c) Service industries: Cleaner Production involves incorporation of environmental considerations into design and delivery of services.

2.8.1. Cleaner Production in Dairy Processing Industry

In dairy processing industry, Cleaner production is a tool which offers new opportunities for optimization in business by complying with the environmental regulations and this is in support of sustainable development (FAO, 2005). Cleaner production techniques and

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technologies use raw materials, energy and other material inputs compared to conventional end-of-pipe approaches.

The approach produce less waste, facilitate recycling and reusing resources and handle residual wastes in a more acceptable manner. These methods have significant advantages in terms of financial and economic as well as environmental benefits at both local and global level (Ananda, 2008).

As mentioned earlier, even though dairy processing occurs world-wide but the structure of the industry varies from one country to another. Organic materials, suspended solid waste such as coagulated milk, particles of cheese curd, in ice-cream plants pieces of fruits and nuts and other substances and materials such as phosphorus, nitrogen, chlorides, heat and acid or alkali content of liquid wastes happens to be the major pollutants in the dairy processing wastewater (Dierks, 2011). These pollutants come from the wasted materials, which are basically milk and milk products, lubricants (soap and silicone based) used in certain handling equipment, sanitary and domestic sewage, non-diary and milk by products such as whey and sometimes buttermilk (HDC, 2008). Typical water uses and sources of effluent in a dairy are given in Figure 2.4.

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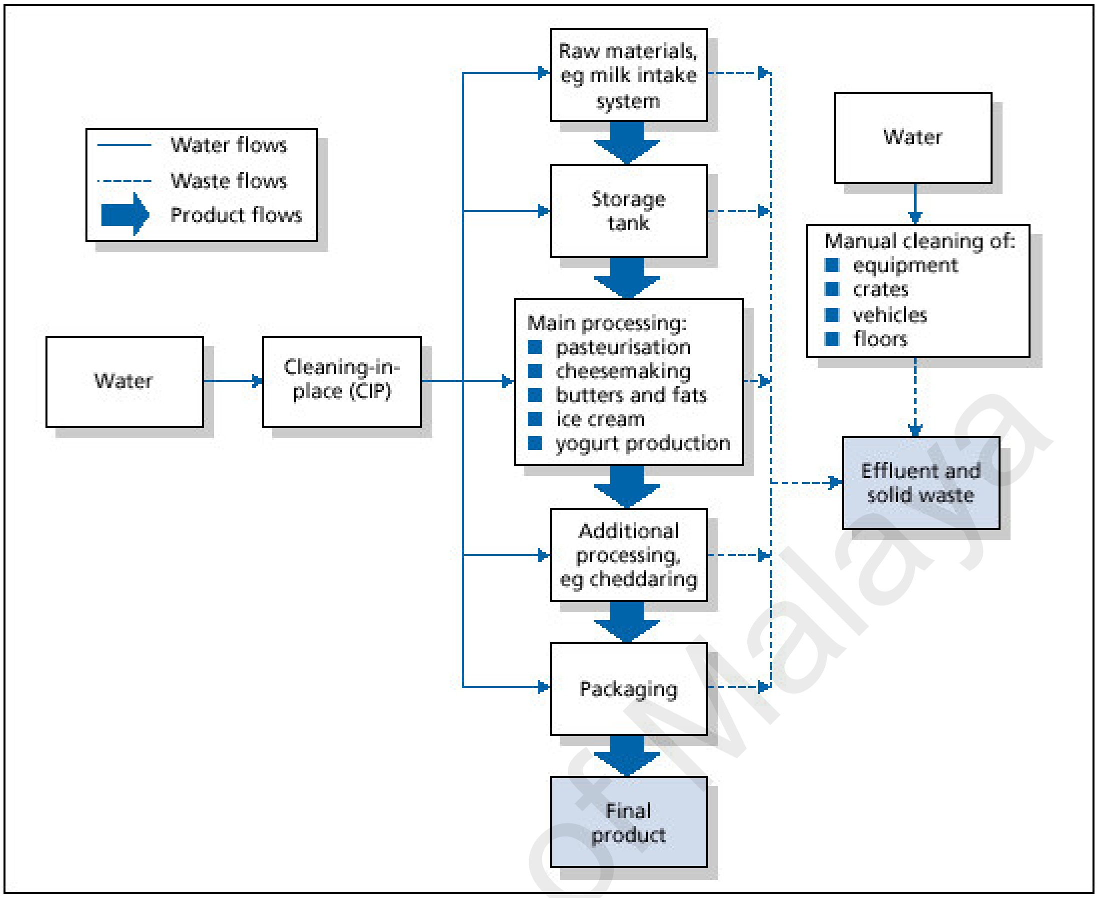

Figure 2.4. Typical water uses and effluent sources in a dairy (UNIDO, 2008)

2.8.2. Cleaner Production Opportunities

There are several opportunities for the market when it comes to then milk-related production and products.

Clean water recycles: Excess water service used for the clarifier and separator for keeping the equipment clean. The steam condensate has good water quality and are being discharged to channel. These sources may be recycled for sludge liquidification in clarifier and separator operations or used in cleaning operations (OECD, 2008).

GHK/repair: Repairing of valves of clarifier, HTST pasteurizer fittings, cooling water line in deodorization and changing of the damaged hose in homogenization will eliminate discharge of 2,037.3 kg/day of service water (Porter, 2008).

Off-site reuse/milk sludge: In terms of organic load, the issue with clarification and separation, is the milk sludge discharged to sewer. It is a valuable source as animal feed due to its nutritional value. AOC is a large facility that also feeds cattle so the sludge can be used in their feeding or it may be used in fodder industry, some of which are found in the vicinity of Ankara. To this purpose, collected sludge may be kept in refrigerated storage for weekly transfer of it to fodder industry (Porter, 2008).

Off-site reuse/milky water: The water from the first rinsing can be collected in a tank and used for watering cattle similar to the case with milk sludge. Due to the content of milk, animal fed with this source will have higher milk production efficiency (OECD, 2008). In this approach, to prevent milk spill on floor, raw milk storage tanks can be connected to a single pipe, which will be connected to pasteurization and flow from three tanks which is manually controllable. By this system, milk spill to ground and first rinse wastewater of this tanks could be collected at the end of new pipe.

GHK/ small equipment change/water & milk: During operation of separator, excess of water used for liquidification of sludge overflows from the tank and disposed to channel. If a level control is affixed to the tank in which service water is stored for separator sludge, this discharge which in this case study is about 2,100 kg/day, could be eliminated. During filling, the vessels to be sold as unpacked milk 45.2 kg/day of milk spills due to valve remained open

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and overfilling. If the global valve used to control the milk pipe is replaced with a check valve and if this is closed at every vessel change, this spill will be prevented (Sungkar, 2008).

GHK/operating Practices/milk: Milk due to defective packaging (carton or bottle) and remaining in the pipe is already collected in vessels and send to the starting of each process. If defective packaging is minimized, amount of milk returned will be reduced that will prevent use of chemicals, energy and water once again for the same amount of milk (OECD, 2008).

2.8.3. Material Flow Cost Accounting (MFCA)

Material flow cost accounting or in short MFCA, is a management tool that assists organizations in better understand the potential environmental and financial consequences of their material and energy practices and seeks to improve them via changes in those practices (Fink, 2013). It does so by assessing the physical material flows in a company or a supply chain and assign adequate associated costs to these flows. The method was developed in Germany in the 1980s and is related to approaches such as eco balances, flow cost accounting and "Reststoffkostenrechnung" (Wagner *et al*., 2010).

The method became a huge success in Japan in the 2000s. By the year 2010 up to 300 companies had applied the MFCA approach, which was highly supported by the Japanese government. In 2011, the International Organization for Standardization (ISO) published a norm on MFCA (i.e. EN ISO 14051:2011). The aim of MFCA is to enhance both economic and environmental performance through improved material and energy use (M.v, Hauff *et al.,* 2012*)*. Since 2011 a general framework for MFCA has been provided by the ISO 14051 norm. In order to improve material and energy efficiency MFCA aims to increase

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transparency regarding material and energy flows and the respective costs in supporting organizational decisions in areas such as process engineering, production planning, quality control, product design and supply chain management. Next is to improve coordination and communication on material and energy use within organizations (Fink. 2013).

Many manufacturing companies are not always clear about their real production costs. Often, costs for material losses are only associated with the direct disposal costs. However, further costs need to be assigned to rejected or disposed materials to obtain the total financial impact of material losses. There are the material direct costs on the one hand and further costs in upstream processes caused by transportation, energy, auxiliaries, etc. on the other hand which all need to be taken into account. Against this background material flow cost accounting aims at calculating hidden costs as they can highly influence the economic relevance of material losses. After all, this concept is used to improve the efficient use of material and energy.

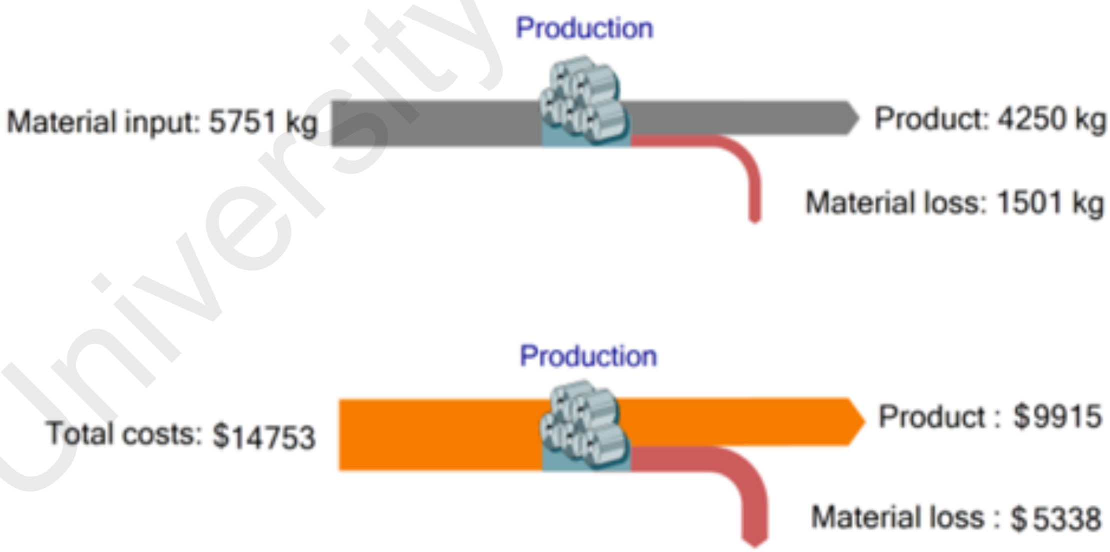

Figure 2.5: Material input and total costs for a product

2.8.3.1. ISO 14051: Standard approach for Material Flow Cost Accounting

The International Organization for Standardization (ISO) published the ISO 14051:2011 to offer a general framework for Material Flow Cost Accounting (MFCA).

The standard assists companies with the implementation steps of MFCA including the development of a material and energy flow model for the quantification of material, energy, system and waste management costs, the communication of the MFCA results and the identification of improvement opportunities.

While companies are still collecting experience with ISO 14051, the planned ISO 14052 standard 'Guidance for practical implementation in a supply chain' will be describing how to do a Material Flow Cost Accounting (MFCA) along the supply chain.

2.8.3.2. Practical Examples of MFCA Application

Internationally the material flow cost accounting has primarily been disseminated in Japan where more than 300 manufacturing companies already applied the concept, though the method was originally developed in Germany. Small and medium sized enterprises have started using the material flow cost accounting to assess their product systems and to render them more efficient.

Here are some examples of application of MFCA:

A small furniture manufacturing company in the Czech Republic has been producing furniture mainly made of chipboards. The production model for the MFCA comprises five main process steps. All processes have material losses that sum up to 9.22% of input raw material and nearly 11% of the total production costs. The accumulated material losses cost the company 25793 CZK (1,377 USD) per month.

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A large metal processing company in Germany produces flexible metal components and had sales of more than 500 million Euros in 2013. An MFCA revealed that in total they have 36% material losses compared to the input material. The entire production consists of eight process steps. The second process step has material losses of more than 75 kg whereas the sixth process step has the second highest amount of material loss with about 35 kg. Surprisingly, the total cost for the loss of the sixth process step is twice as much as the total cost for the material loss of the second process. This clearly shows the importance to consider the embedded cost due to additional system and waste management costs.

The Mitsubishi Tanabe Pharma Corporation manufactures medical products in Japan. The MFCA identified total material losses worth 1,372 billion JPY (12.7 billion USD) annually, nearly 50% of the total production costs.

2.8.3.3. Difference between material flow cost accounting and conventional costs accounting

MFCA represents a different way of management accounting. In conventional cost accounting, the data are used to determine whether the incurred costs are recovered from sales. It does not require determining whether material is transformed into products, or disposed of as waste. In conventional cost accounting, even if waste is recognized in terms of quantity, the costs to produce "material losses" are included as part of the total output cost. On the other hand, MFCA, as explained before, focuses on identifying and differentiating between the costs associated with "products" and "material losses." In this way material loss is evaluated as an economic loss, which encourages the management to search for ways to reduce material losses and improve business efficiency.

The differences between MFCA and conventional cost accounting do not mean that MFCA cannot be applied to any organization that uses materials and energy. In other words, MFCA

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does not demand any specific requirement in regards to the type of product, service, size, structure, or location. In addition, MFCA can be expanded to multiple organizations belonging to the supply chain. This will enable the organizations to identify even more opportunities for material reduction as well as higher energy efficiency. Wider MFCA scope than that for a single entity is especially helpful because waste generation in an organization is occasionally derived from materials provided by a supplier or demanded by customers/consumers.

Material flow is constituted by three main elements:

1. Material
2. Flow
3. Cost accounting

1. **Material**

Material refers to any raw material, auxiliary material, component, catalyzer, or part that is used to manufacture a product. Any material that does not become part of the final product is considered material loss. In any process, waste and resource loss occur in different steps of the process, including:

a) Material loss during processing, defective products, impurities
b) Materials remaining in manufacturing equipment following set-ups
c) Auxiliary materials such as solvents, detergents to wash equipment, water
d) Raw material that becomes unusable

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2. **Flow**

MFCA traces all input materials that flow through production processes and measures products and material loss (waste) in physical units using the following equation:

Input = Products + Material loss (waste)

The starting point of MFCA is to measure the amount of material losses based on mass balance. Decision-making in organizations typically involves financial considerations. MFCA supports this point by assigning a monetary value to material losses. In detail, MFCA allows organizations to see material losses as "products" rather than "waste" even though they are not marketable. This indicates that costs for both products and material losses are calculated in an equivalent manner. Therefore, all costs caused by and/or associated with the material flows entering and leaving a quantity center must be quantified and assigned or allocated to those material flows (Clauses 3.14, 3.16, 5.2, ISO 14051:2011).

3. Cost Accounting

Under MFCA, the flows and stocks of materials within an organization are traced and quantified in physical units (e.g., mass, volume) and assigned an associated cost. Under MFCA, four types of costs are quantified: material costs, system costs, energy costs, and waste management costs. Each cost is defined as follows:

a) Material cost: cost for a substance that goes through a quantity center (measurement unit of input and output for MFCA analysis). Typically, the purchase cost is used as the material cost.

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b) Energy cost: cost for energy sources such as electricity, fuels, steam, heat, compressed air.

c) System cost: cost incurred in the course of in-house handling of the material flows, excluding material cost, energy cost, and waste management cost.

d) Waste management cost: cost for handling material losses

Following identification of a physical unit for material flow data, material costs, energy costs, and system costs are subsequently assigned or allocated to quantity center outputs (i.e., products and material losses) based on the proportion of the material input that flows into product and material loss. The resulting cost of the material loss can become an incentive for organizations and managers to reduce operation costs by reducing material losses. Therefore, it can be said that MFCA can help organizations simultaneously achieve financial benefits and control of material losses (i.e., more effective resource use) (Clause 5.3, ISO 14051:2011).

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CHAPTER THREE: MATERIALS AND METHODS

3. Introduction

In order to fulfil the objectives of this research, scope of the study was set to factory border and production as shown in figure below.

Figure 3.1: Research Boundary is inside the factory and production line

As explained in previous chapter, when it comes to the cleaner production, the process flow of the operation was the most important element that needed to be totally understood. So, after setting the boundary, based on process flow, massive data collection on raw materials, products, wastes energy and stocks needed to be done in which both MFCA and LCA were used.

As MFCA was relatively new method (just became ISO 14051 standard on September 2011), there were not many academic literature on the topic. Therefore, the same approach that the previous cases which had improved their environmental and operational efficiency by MFCA would be assigned as examples. In addition to that, ISO14051 Guideline on Environmental Management- Material Flow Cost Accounting- General Framework was the main reference for fulfilment of second and third objectives. Data needed to be collected according to the input and output material and required energy for each process. In addition to that, data on production, labour cost, machine, utilities were essential. ISO9001 had already been certified to the factory and as a result, it was expected to have data on its production. If there was a data gap, or no data available, the process of data collection could be collected by interviews. After data collection, data analysis was done based on the objectives and possible scenarios were proposed and results of them were considered. Functional Unit for LCA study was also set to 1 tonne of Chocolate Crunchy Cone (CCC) ice cream.

3.1. Research methodology qualitative approach

There were four objectives identified for this research and to fulfil them all, different approaches recommended by MFCA took place. The first objective was to ascertain the process flow and establish material flow balance. As mentioned earlier, this is the most important step in MFCA. Identifying the process flow based on the boundary of the study is the first stepping stone for completing a research based on MFCA method. In order to obtain and understand the process flow, intensive interviews were conducted with the factory management and those in charge of factory production line. The main reason this interview had to be done was to identify the areas that MFCA needed to be applied, to identify the scope of the study and to draw the boundary of the factory and after that find out the people and machines to collect data from. The selected area should not be too big so massive data collection would be required and not too small so the collection of data would be mere and no significant results could be concluded by the study. The main questions were asked during the first step were as below (Jaroslava Hyršlová *et al.,* 2011).

a) How many types of ice cream did they produce?
b) Which ones did they produce the most?
c) What were their ingredients?
d) How did they keep the ingredients?
e) Who were the people in charge and how did they handle the ingredients?
f) How did they handle the wastes from their raw materials, packaging and wastewater?

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g) Which product did generate the most profit?

h) Which product did they believe generate the most wastage?

i) Which product did they think could be a good study subject so the improvement of its production could result in visible possible positive impact?

The answers to the above questions clarified our scope in terms of product and its flow. By identifying the actual study area, it would become clear to start establishing the material flow balance to complete the first objective. Picture below shows the approach to identify the first objective of the study.

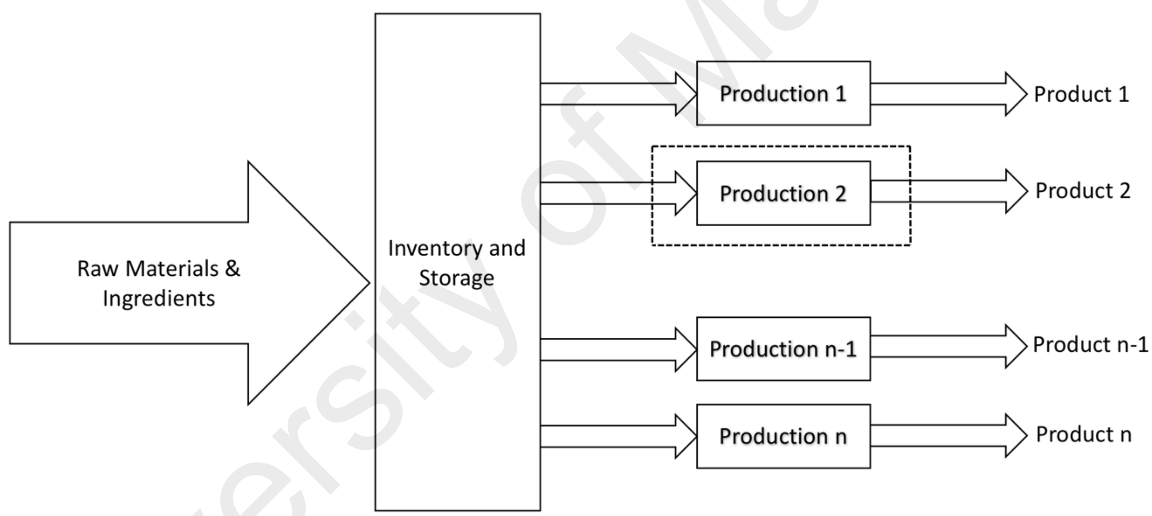

Figure 3.2: Factory's layout and products and selected product for the study

According to Figure 3.2, the layout of whole factory and its products was drawn. Then after first round of interviews, specific area for process flow was identified (i.e. production 2) so by end of the interview, it would become clear that what would be the input and output for that specific product.

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3.2. Research methodology quantitative approach

The second objective of the study was to identify the types and sources of wastes. To do so, it was required to understand the whole process flow in more details. In another word, every single material from the first step of the process had to be measured and registered and followed to the next steps. Some of the processes were from one container to another container and therefore measuring the input and output of the material would not be possible. However, it was suggested that we could study the wastewater from washing the containers to identify the possible residue in those containers as discussed in the literature review, however it was decided to leave that part out of this study as the factory did not have a proper wastewater collection and treatment. So to fulfil the second objective, an excel file was prepared to register the input of raw material, waste type and their amount. This data was later used for the calculation of the waste in monetary units. Figure below shows how this data collection was conducted (Schmidt *et al*., 2013).

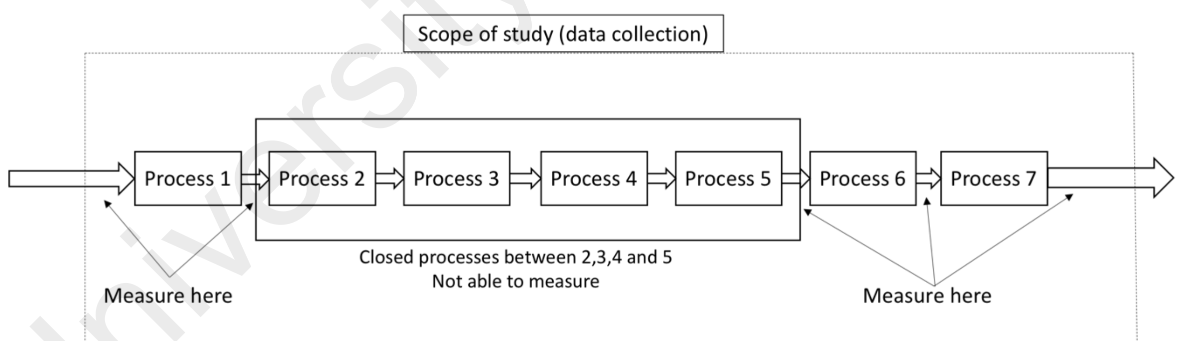

Figure 3.3: Scope of the study and processes which can be measured

As it be seen in figure 3.3, the data before and after process 1 was collected however, processes 2,3,4 and 5 were from one container/tank to another and therefore did not have any way to measure input and output. The related data for processes 6 and 7 were collected accordingly. This step was crucial for the third objective of this study which was converting all the collecting data from the processes into the monetary unit. The approach for this stage was a simple calculation. However, as MFCA has indicated, the waste in further processes even if their materials were identical to the first stages, but the cost would be higher as more resources and energy were used to produce them (Kasemset *et al*., 2016). As mentioned in previous chapter, in MFCA wastes were addresses as negative products which would mean the same amount of energy and resources were used to produce them.

3.3. Research methodology data analysis, discussion and repeat

The last item of the study would be the proposal on improvement measure on the specific product based on MFCA approach. By considering that by the end of third objectives, all the data were collected and carefully analysed therefore all the positive and negative aspects of the production were identified. So to address this issue, there were couple of interview sessions with the management and people in charge of the production lines (only related to the specific product of the study) and the results were shared and discussed. The points were most expensive wastes were created were identified and countermeasures were recommended. Some of the recommendations were applied and after that the second round of data collection was done to find out if the recommendation were effective. The comparison would be based on the previous data from the same process and unit so it would be known if the generated waste or negative product was less (Chang *et al*., 2015).

In summary, the methodology started as qualitative data collection in forms of interviews with those in charge and then quantitative data collection from different processes was conducted and analysed. Some data in this stage could not be collected due to the lack of access (closed flow) but it was suggested to calculate the waste based on the residue in the wastewater from the washing processes (as discusses in previous chapter) which collection

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of the data was not possible. And finally, another qualitative data was done which resulted in recommendation according to MFCA guidelines.

The physical and monetary quantification of the material flow can be summarized in a format that is suitable for further interpretation, for example, in a material flow cost matrix. The data should first be summarized for each quantity centre separately and then other inputs such as energy and system and waste management to be calculated as well. An example of it would be table 3.1 of the summary of the MFCA data for one quantity centre. The table is just an example as there was no data in energy, system and waste management for this research. After the MFCA analysis is completed, the results should be communicated to all relevant stakeholders. In addition, management can use MFCA information to support many different types of decisions aimed at improving both environmental and financial performance. Communicating the results to the organization's employees can be useful in explaining any process or organizational changes and gain full commitment from all members of the organization (Clauses 6.9, 6.10, ISO 14051:2011).

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Table 3.1: Example of a material flow cost matrix for a quantity centre.

Cost	**Material**	**Energy**	**System**	**Waste Management**	**Total**
Product	Example amount (85%)	Example amount (75%)	Example amount (60%)	N/A	Total product (example) (78%)
Material loss	Example amount (15%)	Example amount (25%)	Example Amount (40%)	Example amount (100%)	Total material Loss (example) (22%)
Total	Amount (100%)	Amount (100%)	Amount (100%)	Amount (100%)	Total (100%)

In general, the review and interpretation of summarized data would allow the organization to identify quantity centres with material losses that have a significant environmental or financial impact. These quantity centres could be analysed in detailed form. Data from individual quantity centres can also be aggregated for the entire target process being analysed.

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Any form of Cleaner Production practice would require collection of data, analysis, identify issues, propose and apply solutions and then observe the changes by collecting data and analysing them. In another word, it would be continuous effort. MFCA would not be exception from this common practice so repetitive data collection and analysis would also be required.

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CHAPTER FOUR: RESULTS AND DISCUSSION

The first objective of this research was to ascertain the process flow and establish material flow balance. To do so, the best approach to get the results was qualitative data collection based on the interviews. As it was already discussed in the introduction, the factory produces more than 300 types of ice cream and each one has its own process flow. So after intensive interviews with the factory management and those in production line, it was decided to study production of Chocolate Crunchy Cone (CCC) as it was the most produced and sold product of all. After selecting the product, the whole process from the beginning (receiving & storage of raw materials) till the end (delivery) was observed and notes were taken. While observing the whole process, interviews were conducted with those in charge of different processes such as forklift driver in storage process and operators in preparation and weighing of the ingredients.

4.1. Process Flow

Based on the previous observation of MFCA cases, it was a common practice to write down each process and their input and output on sticky notes, put them all together in a wagon shape format and then discuss them one by one in the details with those involved in each process to be certain that the whole process flow and their inputs and outputs are totally understood correctly and nothing is omitted. Figure 4.1 shows how a sticky note in MFCA approach considers all the input (materials, energy, labour) and outputs (product and waste).

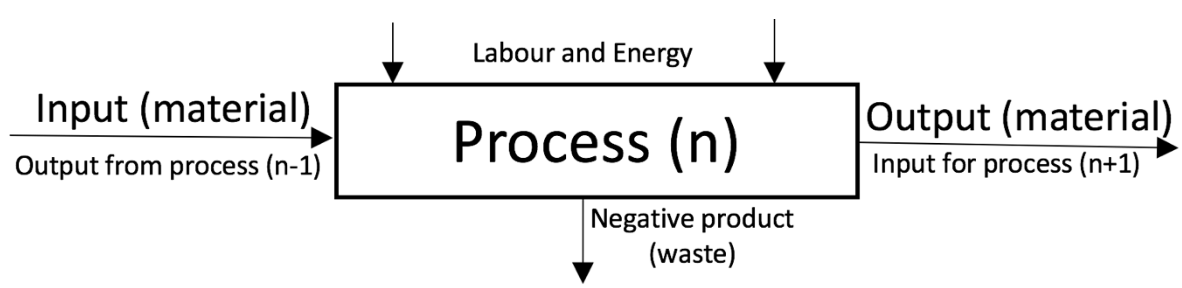

Figure 4.1: An example of a sticky note with all their inputs and outputs

After putting all the sticky notes together, the process flow of the product in a whole picture was drawn and discussed in more details. Diagram below depicts the process flow of CCC ice cream and explanation of each process which was obtained by questioning the operators of each process.

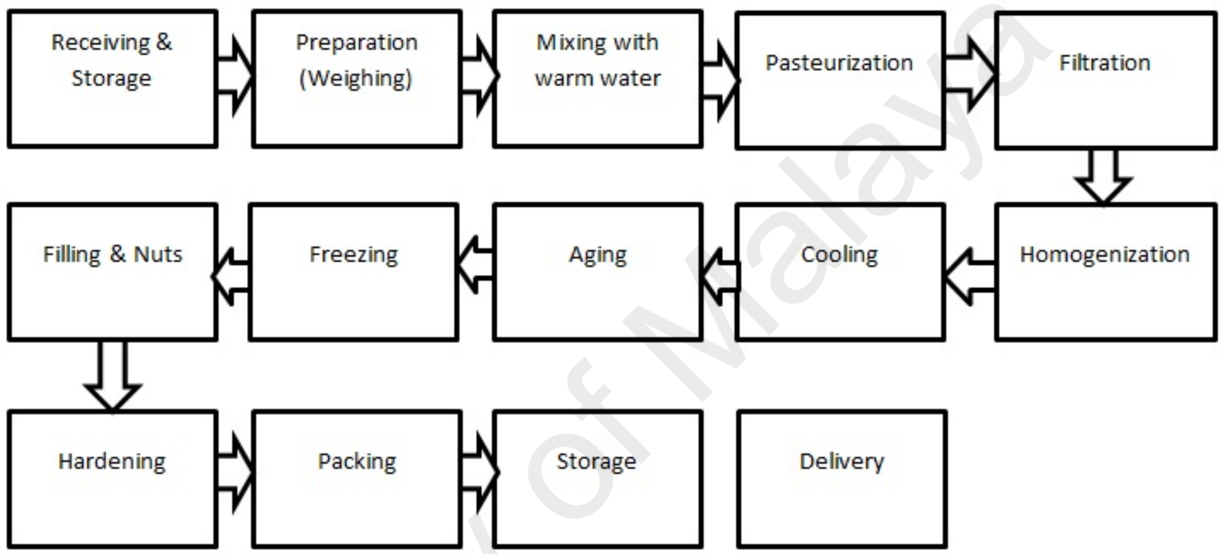

Figure 4.2: Process flow for Crunchy Chocolate Cone ice cream

Receiving and storage: Two types of forklifts (diesel and electric) were active in the area.

Preparation and weighting: Raw materials required for the product were taken out, weighed and would be sent to the mixing tank. Each time (each batch) raw material was collected as one tonne. But from the mixing tank it would for different products. What was learned at this stage was that how much raw materials had gone in and how many different products had come out.

Mixing and pasteurization: Both processes were done in a same tank. All raw materials would be mixed with warm water from 40 degree increasing up to 80 degree. Water was filtered (filter would be changed annually) and heating process was done by a boiler and steam. Boiler used diesel and the rest of the steam was wasted. However, new boiler was being replaced which could recycle the steam back into the boiler. This process would take 45 minutes which 10 minutes of it was allocated for pasteurization (holding).

Filtration: This process was done to ensure there would be no external contaminants or unsolved raw material. Filter would get cleaned after every batch (1 tonne).

Homogenization: Would break down the fat and other molecules. This process was not holding but on-going.

Cooling: was done through the heat exchange. Cold water in the pipes would exchange its heat with the mixture. Temperature would drop down to 10 or even lower and the water would go back to the cooling tower.

Homogenization and cooling processes would take 1.5 hours for each batch.

Aging: There were nine aging tanks in the factory which each product would go to a separate tank. This process was done for at least 4 hours. Temperature would drop down to 4-9 degree and it was done for the texture of the ice cream.

Freezing: Air would get injected during the freezing process so as a result it would make the ice cream ready for filling. There was no filtering process for air.

Filling: This process was done by machine and labour. Filling process was also in charge of the lidding and sealing. At this stage, some samples would be taken out to be weighed.

Hardening: Ice creams would get frozen and kept in a room with -25 degree for at least 4 hours.

Packaging: In this process, coding for expiry date and bath numbers and the whole packaging were done by manual labour.

Storage: Ready products would be kept cool in the storage room with temperature of -18 degree.

Delivery: Trucks would deliver the products to the customers.

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So, in more details and based on the process flow described above, first the raw materials were received from suppliers and stored. At the beginning of each production, raw materials (ingredients) were picked and weighed. After that warm water would be added to them and was mixed with the ingredients (using steam from a diesel boiler to heat the water). Usually the ratio of water and ingredients were about 70-30 in which is 700 kg would be water. Mixing and pasteurization was done in the same tank for about 45 minutes in which 10 minutes would be holding for pasteurization. Next step was filtration to be sure no external contaminants and unsolved ingredients could pass through and the filter itself was cleaned at the end of each batch which as mentioned would be 1 tonnes of mixture. After mixtures was filtered, it would be the time for homogenization which would be an on-going process and was used to break down the fat and other molecules and make the ice cream in one shape. Next step was cooling process which would cool down the mixture to 10 Celsius degree or lower. Homogenization and cooling together would take 1.5 hours. When ice cream mixture was cooled down enough, it would go for aging process which basically would take up to 4 hours with temperature of 4 to 9 Celsius degree. Next step was called freezing which air would be getting injected into the ice cream mixture while temperature slowly would come down. Injecting air would give fluffy texture to the ice cream and would make it to what we would know as an ice cream. After freezing process, ice cream would be ready for filling process which was simply injecting the ice cream mixture into cones and then would add chocolate chunks and nuts and then would put a lid on top of it. After filling, all ice cream would be sent for hardening process in a room with temperature of -25 Celsius degree for 4 hours. After that it would go for packing, storage and delivery. From the mixing process till freezing, all processes would be done from one tank to another and in a closed loop.

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Therefore, apart from very tiny leakage, there would no waste of material. However, part of these materials stay inside the machines as stock and residue which would be known after material balance study was done or as mentioned in the chapter 2 could be calculated by analysing the wastewater from the washing process.

Filling and adding chocolate and nuts process would use machine and labour. In this process, preliminary data collection showed up to 4% loss due to the machine jam at the beginning of the operation or in the middle.

Data collection which was started after understanding the process flow had its own challenges as each batch of ice cream (1 tonne) is used not only for CCC ice cream but for other products (including cups and buckets). Therefore, material balance of CCC ice cream required material balance of other products which share the same batch. Another issue was with the weight of the product as during the freezing process, air is injected which would add more weight to the mixture. Amount of injected air is unknown and that have caused some issues in the numbers.

4.2. Identifying the Quantity Centres

In order to fulfil the second and third objectives of this research, quantitative data collection was required. Based on MFCA guidelines, three different Quantity Centres (QC) were identified. Each quantity centre would have an input and output so the material balance could be done as a comparison of the input and output (waste, product and stock). As figure 4.3 depicts, the quantity centres were identified as Preparation and Mixing with warm water, Filling and nuts and the last one as packing.

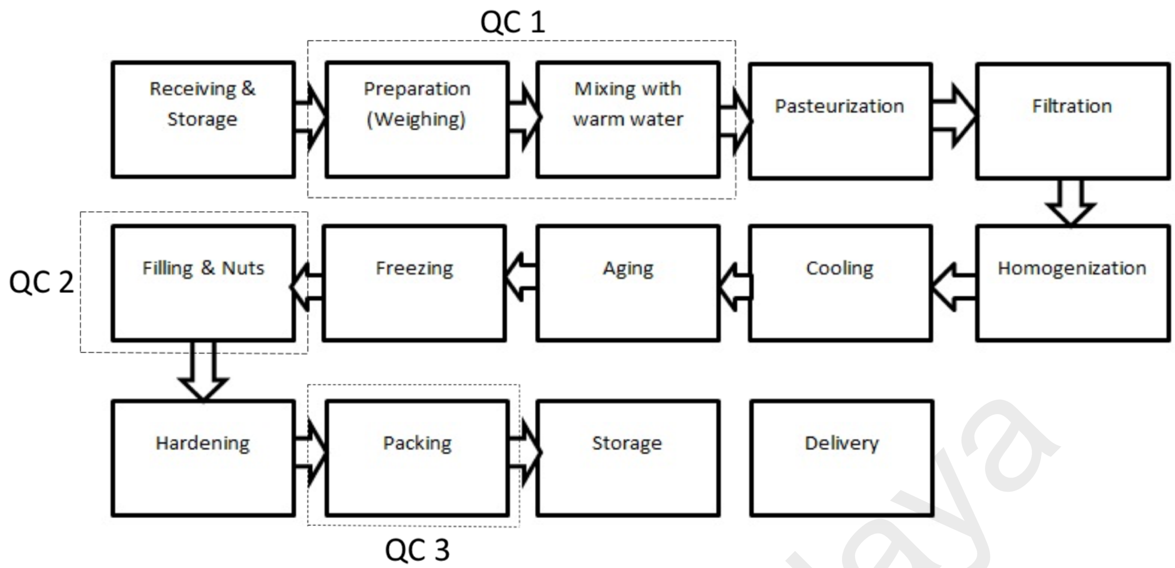

Figure 4.3: Quantity Centres 1, 2 and 3

a) QC1 (Preparation and Mixing): input would be all ingredients and water and output would be ice cream ready mixture and any difference in input and output would be the amount of stocks and residue in the tanks;

b) QC2 (Filling & Nuts): which would have ice cream, cone, nuts, chocolate and lid as input and their weight were calculated;

c) QC3 (Packaging): which calculation of weight of cardboard, tape and products was done.

4.3. Quantity Centre 1 (Preparation and mixing)

As explained in section 4.1, QC1 would be on preparation (weighing) and mixing with warm water. As it can be seen in Figure 4.4, there were five different inputs including the output from previous process (receiving & storage), raw materials (choosing the right ingredients for this product), water, diesel for the boiler to heat up the water and labour. The outputs for this QC were the mixture of the ingredients which would go for the filtration process and waste.

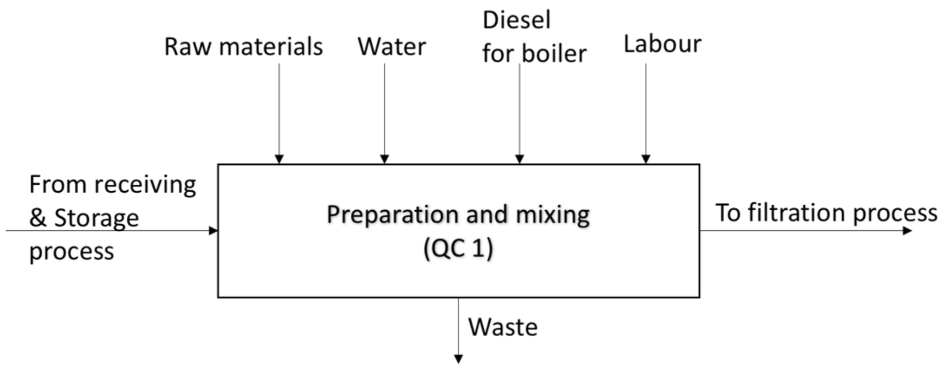

Figure 4.4: Quantity Centres 1 and its inputs and outputs

As explained earlier, the mixture was usually ratio of 70% water and 30% ingredients so equivalently the input would be 700kg of water and 300kg of raw materials. The amount of diesel could not be calculated as there was no logged data on its fuel consumption. The generated wastes for QC1 were identified as spillage of water and ingredients during the preparation process, and steam from the boiler which was emitted. Table 4.1, gives the summary of QC1 including its inputs and outputs.

Table 4.1: Inputs and outputs of Quantity Centre 1

Input	**Water (kg)**	**Ingredients (kg)**	**Diesel (litre)**
Amount	700	300	N/A
Output	**Mixture of ingredients (kg)**	**Spillage**	**Steam**
Amount	1,000	Negligible	N/A

There were basically only negligible wastes from water and ingredient spillage which could be totally ignored. The boiler steam however, is being emitted and that could have negative environmental impact. The amount of the emitted steam was not collected due to the existing plan to change the boiler into a new closed-loop boiler so the emitted steam could be used for the heat exchange with the water going into the mixing tank.

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4.4. Quantity Centre 2 (Filling & Nuts)

After QC 1, all the mixture would go through different processes which were all closed loops from one tank to another. After the freezing process was done the ice cream would be ready to be filled inside the cones. Figure 4.5 depicts the inputs and outputs of this quantity centres.

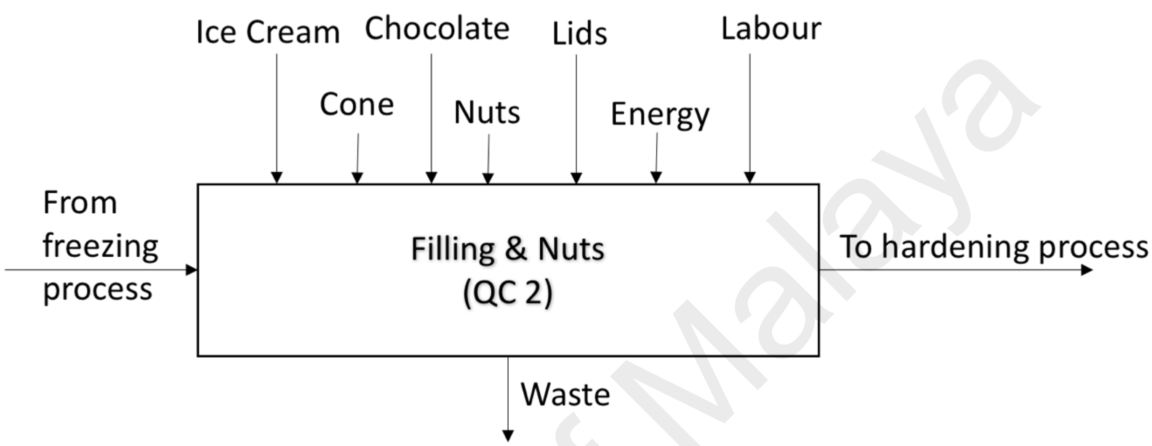

Figure 4.5: Quantity Centres 1 and its inputs and outputs

Filling process was done by both machine and labour. Labours would put the cones on a tray and then the machine would automatically fill the ice cream mixture into the cones, would add chocolate and nuts and then press the lid on top of the cone. Then another labour would take the cones on another tray for transferring them for the hardening process. Every few batch, some of the ice creams would be taken for weighing to ensure that the quality of the ice creams would comply with the rules and regulations.

The waste in this QC was identified as spillage of ice cream, spillage of chocolate and nuts as well as waste of cones and lids. In this process by considering that the wastage of each of the mentioned substances would be small therefore, slightest slippage in any of them would cause a defect in the whole ice cream and as a result, the whole product would be considered as waste. So in this quantity centre, instead of collecting data on each substance, the total number of produced ice cream as well as the total number of defected ice cream were

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calculated and analysed. Table below shows the number of produced ice cream for 6 months, starting from August 2013.

Table 4.2: Number of produced CCC ice creams for 6 months since August 2013

Aug	Sep	Oct	Nov	Dec	Jan
21,089	12,734	32,275	58,575	7,925	11,297

According to the table 4.2, factory by average, produced 23,983 CCC ice cream per month. The data for defected ice cream were also collected for the same period which is shown in table 4.3.

Table 4.3: Number of defected CCC ice creams in the filling process starting August 2013

	Aug	Sep	Oct	Nov	Dec	Jan
Filling	526	269	304	912	76	65

After data collection on the defected products in filling process was done, another round of interview with the filling machine operators was conducted to find out the main reasons for the defects in the product. The main reasons were listed as:

a) Jammed filling machine (particularly at the first hours of the operations)
b) Jammed chocolate and nuts crusher machine (particularly at the first hours of the operations)
c) Broken or defected cones (either from the supplier or mishandled by the operators)
d) Mishandling the product while transferring them for the hardening process

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There was no available data on how many products were defected for which of the above reason as all for them would be marked as defects. The less defected products in December 2013 and January 2014 were not due to improvement in the process but due to less production (only 76 units in December and 65 in January) because of fixing the filling machine.

As mentioned earlier, the total waste in this quantity centre would be all the ingredients as well as the product itself, however, by considering that the measuring the amount of spilled ingredients would not be calculable, then wastage unit was set to the whole product. Therefore, by knowing that how much each product would cost (cone, cover, lid, ice cream, chocolate and nuts) without calculating the energy and labour cost, each defected product would have a monetary value which is shown in Table 4.4.

Table 4.4: Cost of defected ice creams in the filling process starting August 2013 (RM)

	Aug	Sep	Oct	Nov	Dec	Jan
Filling	189.4	96.8	109.4	328.3	27.4	23.4

So by end of January 2014, the number of CCC production, number of defected products, the reasons to cause defects in the products and the cost associated with those defects were identified and calculated.

As discussed earlier in QC1, the factory would prepare one batch each time for ice cream production which includes 1 tonnes of ice cream mixture. However, not all that mixture would be used for one type of the ice cream (i.e. CCC in this research) as the same batch could be used for other types which would be decided weekly by the factory management. Therefore, as it was discussed to have the focus of this study on only one type of the ice

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cream but to be sure that data was collected from one batch of data would be analysed corrected, it was decided to also observe and collect the data from the same 1 tonne batch which would go into other types of the ice cream. The other ice creams which were usually produced besides the CCC ice cream from the same batch were identified as 0.5 litre and 15 litre tub ice creams and their data is listen in table 4.5.

Table 4.5: Data on 0.5 and 1.5 litre ice cream from same batch as CCC ice cream

Production of 0.5 and 1.5 litre ice cream		
Total input	Number	Weight (kg)
Product 0.5L	200tubs	55
Product 1.5L	336tubs	277.2
Tub and lids 0.5L ice cream	200 pcs	7.2
Tub and lids 1.5L ice cream	336 pcs	28.056
Sticker 0.5L ice cream	200 pcs	0.36
Sticker 1.5L ice cream	336 pcs	1.344
Plastic 0.5L ice cream	200 pcs	0.7
Plastic 1.5L ice cream	336 pcs	3.528
Total output		
Product 0.5L		63.26
Product 1.5L		310.128

The collected results from the table 4.5 showed that the production of this type of ice cream (0.5 and 1.5 litre tub) which used the same ice cream mixture as CCC ice cream had not waste in any form. The reasons were due to the different way of handling and filling this type of

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product. In addition to that, unlike delegate and fragile cones, the containers of this ice cream were hard plastic which were much stronger.

4.5.Quantity Centre 3 (Packing)

The next quantity centre to analyse was Packing which was done after the hardening process (keeping the ice cream in the cold room for 4 hours) and it was the last process before the delivery. In this process, products were picked by operators and piled up in the cardboard boxes to be ready for delivery. Figure 4.6 depicts the inputs and outputs of this quantity centres.

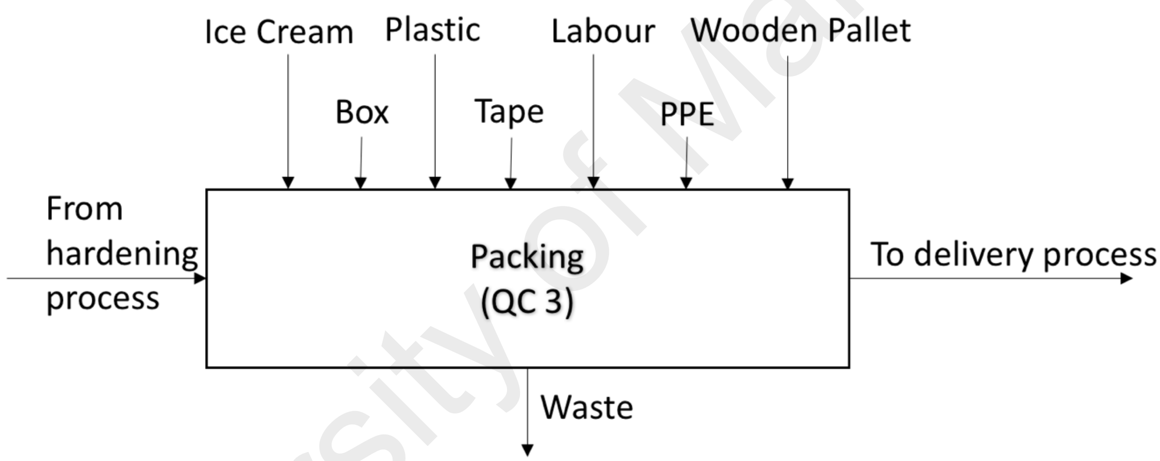

Figure 4.6: Quantity Centres 1 and its inputs and outputs

In packing process, the input would be the ready ice cream, boxes, tapes to seal the box and plastics to keep the boxes sealed so the whole package would not get contaminated during the delivery process.

The waste in this QC was identified as product itself, boxes, plastics, tapes, PPE (Persona Protective Equipment) and wooden pallets. The data from input and output were analysed however, the focus remained on the product defects so the comparison on the same waste type could be done from two different quantity centres. Table 4.6 shows the total input into the hardening process (as output of filling process) and the input into the packing process (as an output of the hardening process) to identify the possible material loss.

Table 4.6: Quantities of packing process

Quantity Centre 3: Packing & Hardening		
Total Input to QC3		**Weight (kg)**
Product		206.61
Packaging Material		0.306
Total output from QC3	**Number**	**Weight (kg)**
Product	71box	195.25
Box	71pcs	5.64
Plastic	71pcs	0.89
Tape	142pcs	0.024

According to the obtained results in table 4.6, total input into the packing process which were identified as product, boxes, plastics and tapes, had weight of 206.6kg while the after the packing process the total mass of all the materials to be sent to the storage and delivery was only calculated as 201.8kg. Therefore, the material lost was about 4.8 kg.

There had been more data on the same quantity centre (packing process) which had not been collected during the period of study but their results were also helpful to have clearer understanding of the negative products in QC3. Even though this data might not be considered into this study but the waste generated of it could be another endorsement of the collected and analysed data during the period of the study. Details of it is shown in table 4.7.

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Table 4.7: Products and wastes packing and hardening

Packing & Hardening processes		
Total input into hardening & packing	**Number**	**Weight (kg)**
Product		913
Packaging – Boxes	550	78.65
Tape		3.3
Stamp	2 stamps used	
PPE	0	0
Wooden Pallets	4 units	
Total output prom packing		
PPE	0	0
Waste (defect)	136pcs	11.28
Spillage	0	0
Excessive Package – Boxes	30	4.29

From Table 4.7, there was no spillage of the product in this process and the total input of product was 913kg excluding packaging boxes, stamp, tape and wooden pellets. The output of waste was recorded of11.28kg of product and 4.2 kg of packaging materials.

The summary of the collected data for the product defects for the six months period of the study is shown in the table below.

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Table 4.8: Number of defected CCC in packing process starting August 2013

	Aug	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**
Packing	262	128	219	457	39	47

After data collection on the defected products in the packing process was done, another round of interview with the packing operators was conducted to find out the main reasons for the defects in the product and other wastes. The main reasons were listed as:

a) Mishandling the products while transferring them into the boxes

b) Wrong preparation of the boxes

c) Wrong measurement of the tapes (due to human errors) so they would be either too long or too short

d) Mishandling the wooden pallets by forklift operators while transferring them into the cold storage room as well as the changes in the temperature inside and outside of the storage room which would affect the quality of the wooden pallets.

The most important defects in this quantity centre was considered the product itself as the amount and cost of other wastes were negligible and some of them such as boxes and wooden pallets were sent to the recycle centres. Table 4.9 shows the cost of the defected products in the packing process.

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Table 4.9: Cost of defected ice creams in the packing process starting August 2013 (RM)

	Aug	Sep	Oct	Nov	Dec	Jan
Packing	116.3	56.8	97.25	202.95	17.35	20.85

So by end of January 2014, the number of defected products, the reasons to cause defects in products and the cost associated with those defects in packing process were identified and calculated. In addition to that, part of the hardening process was included into the data collection as the output of the hardening process was the input of the packing process.

4.6. Data analysis on all quantity centres

In previous sections, the data from each quantity centre was collected and analysed separately. In the first QC, the waste was negligible and the waste generation could be mitigated by more care and proper handling of the materials as well as a more efficient boiler to send back the steam into the system for heat exchange. The data on residues in the tanks could not be collected due to lack of facilities for wastewater in the factory. However, as discussed in the literature review section, by existing a wastewater treatment plant inside the factory, it would be possible to collect the wastewater from the tanks (while being washed) and then analyse the organic substances in it and calculate the amount of it in the tanks (Dierks, 2011).

Tables 4.3 and 4.8 showed that there were more defected products in the filling process than in the packing process. The ratio between number of product defects of these two processes

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is shown in table 4.10. The ratio was calculated based on the total number of defects in both filling and packing process over number of defects on each process.

Table 4.10: Ratio between number of defects in filling and packing processes

	Total Defects (pcs)	Defect Ratio (%)
Filling	2,152	65.13
Packing	1,152	34.87

The ratio between cost of product defects of these two processes was also calculated and is shown in table 4.11. The ratio was calculated based on the total cost of defects in both filling and packing process over cost of defects on each process.

Table 4.11: Ratio between cost of product defects in both filling and packing processes

	Total Cost (MYR)	Ratio Cost (%)
Filling	774.7	60.13
Packing	511.5	39.87

In conventional material flow analysis methods, the cost would be directly to the amount of wastes. Therefore, it was expected that the ratio between the number of product defects and cost of them in both processes would be same. However, result showed that even though the ratio for product defects in filling process was slightly more than 65%, but the cost of the

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defects in the same process was not 65% but 60%. The difference could be explained in MFCA method as further a product would go from one process to another, the cost of production (either actual product or negative product or waste) would go higher (Jaroslava Hyršlová *et al.,* 2011) (Schmidt *et al*., 2013) (Kasemset *et al*., 2016). So in conventional methods of material flow analysis, the countermeasure to tackle the waste problem would have been on the filling process as it had 65% of the defect products and to find solutions to mitigate the waste generation and reduce product defects inside the process. However, in MFCA approach, by understanding that the product defects in the packing process was not only would waste the ice cream itself but also the materials and energy carried out with the product from filling process to hardening and finally to the packing processes. And that could explain the reason why the ratio of product defect in filling process would not match with the ratio of the cost for the same process. Of course, to understand this in more details, would require calculating the energy and labour costs for these processes and engage Life Cycle Analysis (LCA) and cost assessment into this study as in environmental accounting research, there are a few studies that focus on the active role of environmental accounting (Kitada, *et al*., 2012).

After sharing the findings with the factory management, the decision was made to mitigate the waste generation at the filling process only. Even though MFCA approach clarified that the ratio of cost might be slightly higher in packing process, but the environmental impact would be negligible as the defect product would not be thrown away but consumed internally. The defect from the filling process would be treated as a solid waste while the defect product of the packing process would be still edible but not suitable for sales. Therefore, MFCA also played an important role for making an environmental/economic decision (Chang *et al*., 2015).

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CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

MFCA implementation provides information such as material loss throughout the process, the use of materials that do not become products (also known as negative product), overall costs and the energy associated with the material loss. Managers who are aware of the costs associated with material losses can then identify opportunities to increase efficiency in material use and improve business performance and reduce environmental impacts. Through the identification of MFCA issues that lead to material losses, organizations have a chance to identify the resulting economic loss.

Once MFCA analysis has assisted an organization to understand the magnitude, consequences, and drivers of material use and loss, the organization may review the MFCA data and seek opportunities to improve environmental and financial performance. The measures taken to achieve these improvements can include substitution of materials, modification of processes, production lines, or products and intensified research and development activities related to material and energy efficiency.

By applying MFCA, financial costs such as processing and material losses are identified. In many cases, the scale of the identified costs is more significant than previously assumed. At the same time, MFCA presents an ultimate target for engineers: “the zero-material loss cost” which can encourage the organization to make a breakthrough in the recognition of the necessity for improvement. The typical losses identified by MFCA include the following:

a) Waste treatment cost for material loss;

b) Procurement cost for material losses sold to external recycling contractors;

c) System cost for material losses (labour, depreciation, fuel, utility and other costs);

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d) System cost required for internal recycling of materials; and

e) Material and system costs for in-stock products, work-in-progress materials, materials that were disposed of due to a switch to a newer model, deterioration of quality, or for aging stock.

Furthermore, companies are often unaware of losses associated with recyclable waste because such waste is reused as resources and sometimes sold as valuable material to external recyclers.

MFCA increases the transparency of material flow, which is a key to successful problem-solving and improvement. By solving problems, organizations can increase their resource productivity and reduce costs at the same time. While most organizations monitor the yield, rate associated with the materials used in the process, the general scope of such monitoring only covers the main materials, processes, or losses in many cases. In such cases, MFCA helps organizations highlight uncontrolled material losses.

The last but not least, all the objectives of this research were fulfilled in terms of understanding the process flow of the picked product, defining the correct quantity centres, establishing the material balance and identifying input and output materials and other substances such as energy and labour into each quantity centre, converting the material loss into the monetary equivalent and finally highlighted all the findings to the management and propose a countermeasure for better efficiency in business performances and less environmental impacts.

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SUPPLEMENTARY

1. List of Publications and Papers Presented

1.1. MFCA Implementation in Small and Medium Enterprises (SME) in Malaysia: A Case Study of an Ice Cream Factory

Paper which is published in the Eco Balance 2012, the 10th International Conference on Eco Balance, Challenges and Solutions for Sustainable Society, November 2012 – Yokohama, Japan

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