The University of British Columbia
Department of Chemical and Biological Engineering
CHBE 484 – GREEN ENGINEERING

A LIFE-CYCLE AND ECONOMIC ANALYSIS: BUTTER VERSUS MARGARINE USED IN UBC FOOD SERVICE

APRIL 25, 2007

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April 20, 2007

ATTN: Ms. Brenda Sawada, Ms. Dorothy Yip, Ms. Maria Domingo and Dr. Xi Tony Bi

Dear Ms. Brenda Sawada, Ms. Dorothy Yip, Ms. Maria Domingo and Dr. Xi Tony Bi:

RE: Life Cycle Analyses of Butter and Margarine Used in UBC Food Service

The UBC Food Service has served the campus and the community nearby for almost 80 years and it always continues to upgrade its image of delivering the healthiest and high-quality food to its customers, as well as being environmental-friendly and economical. For this purpose, both the life cycle analysis and economic analysis of butter and margarine are performed.

As a group project of CHBE 484 Green Engineering, we have performed the investigation of manufacturing, packaging, cost, usage, disposal and emissions of butter and margarine. We hope the project will be informative and relevant to the community. If you have any questions or comments regarding it, please do not hesitate to contact us.

Sincerely,

Marina Hu, Gaby Wong, Alice Yu

CHBE 484 Life Cycle Analyses of Butter and Margarine Group

Table of Contents

List of Figures and Tables

List of Figures

List of Tables

1. INTRODUCTION

UBC Food Services has been serving the campus and the community nearby for nearly 80 years and it is 100% self-funded. It provides a variety of services, such as cash operations, residence dining, on campus catering and university centre. In order to maintain please the customers, UBC Food Services has been continuously improving their food quality and help the students to maintain healthy diet. Most of the food provided to students contains butter and margarine. At the same time, UBC campus is continuously developing a more sustainable community; therefore, the objective of this project is to help evaluating the usage of butter and margarine by performing both life cycle analyses and economic analyses.

Butter and margarine are widely used in the different cooking and baking operations of UBC food services. Figure 1 below shows a distribution of their usage on campus. As it can be observed, the usage of butter is more than two times the usage of margarine.

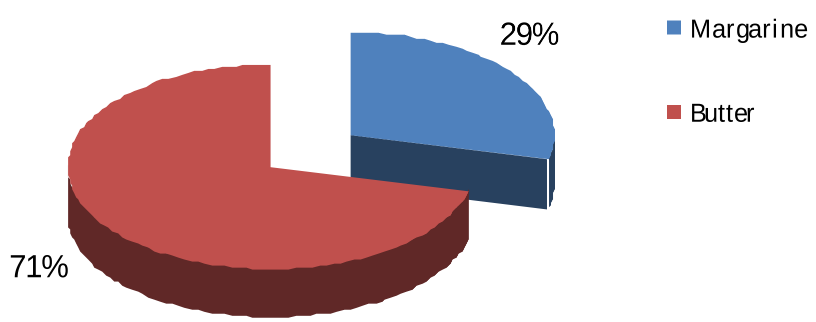

Figure 1 UBC Food services usage of margarine compared to butter

The scope of the life cycle analysis performed in this project is limited to these table spreads used on campus. The aspects that are considered include: raw materials, manufacturing process, distribution and emissions. Comparisons among choices of products can then be performed after completing economic analyses and considering the environmental impacts, which are investigated in this project.

2. Background

The vendors that provide butter and margarine to UBC Food services are mainly Saputo/Neptune and Sysco Vancouver respectively. Saputo is the butter manufacturer as well as the distributor whereas the other two companies are solely distributors.

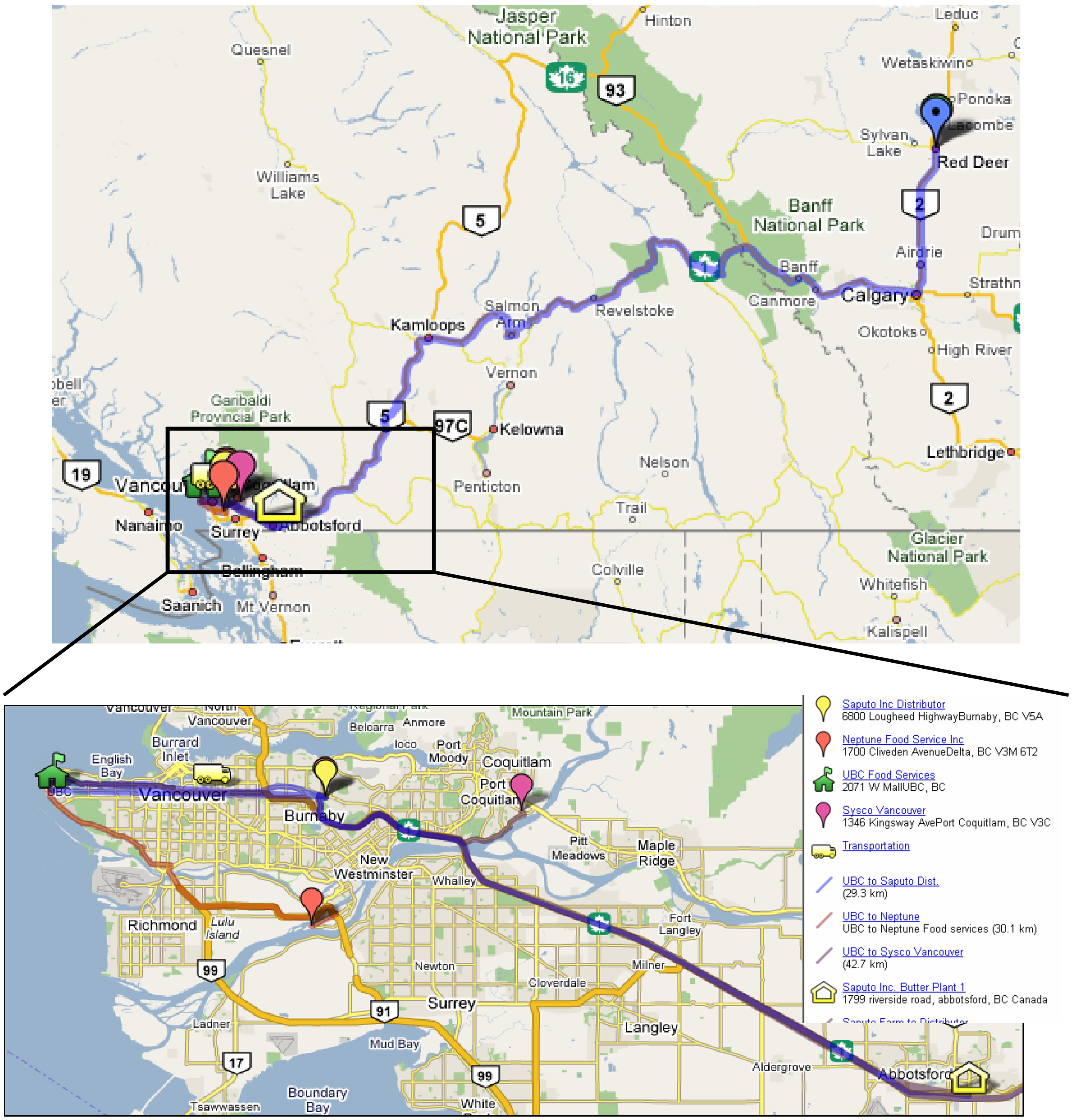

Figure 2 Geographical locations of plants and distributors with respect to UBC food services

The previous figure represents the different distributors with their respective production plant locations. These locations were used for the calculations of food miles. It should be noted that a plant location for the margarine production was not disclosed by the distributor. As the distance information for the latter is not available their distances were assumed to be similar to Saputo's Abbotsford plant.

From the inventory given by the UBC food services, it was determined that about 95% of the cost for solid cooking fats goes to butter. About 52% of the total cost goes to purchasing whipped butter, which comprises about 30% of the total stock. On the other hand, margarine makes up 29% of the volume while only costing 5% of the total.

For the purpose of this project the production capacity will be standardized to the total product purchased by UBC Food Services in a calendar year. Hence, for the butter production our capacity will be 5.7 tonnes per year and for margarine 2.3 tonnes per year.

3. BUTTER

3.1. *Introduction*

Butter is solidified fat made from churning cream with 25 to 40% milk fat until it reaches a composition of ~ 80% milk fat with no more than 16% moisture content. The process is basically a mechanical one where cream (emulsion of fat-in-serum) is transformed into butter (emulsion of serum-in-fat) [14]. Apart from the fatty contents it also contains proteins, calcium, phosphorous (about 1.2%) and fat-soluble vitamins A, D, and E. It is one of the most highly concentrated forms of fluid milk and it requires about twenty liters of whole milk to produce one kilogram of butter. Table A-1 gives some physical properties of butter.

The usage of butter has been recorded for as early as 2,000 b.c. It has been used as a spread, a cooking fat, or a baking ingredient throughout history. Its distinctive taste and flavor captures the cravings of many who are after a culinary treat. This may be a reason why about 71% (Figure 1) of the cooking and baking of UBC food services is done with butter. The following section will describe the processes involved in the manufacture and use of butter specifically those encompassing UBC Campus.

3.2. *Raw Materials*

The raw material for the production of butter is ultimately milk. The average cow will produce about 8839 liters of milk per year and 600 liters of methane (STD) per day.

3.3. *Manufacturing Process and Packaging*

A block flow diagram for the manufacture of butter is shown on the next page. There are essentially 8 major steps to butter manufacture: Separation of components, Pasteurization, Inoculation (optional), Aging, Churning, Draining and Washing, Working and Salting, and finally packaging and storage.

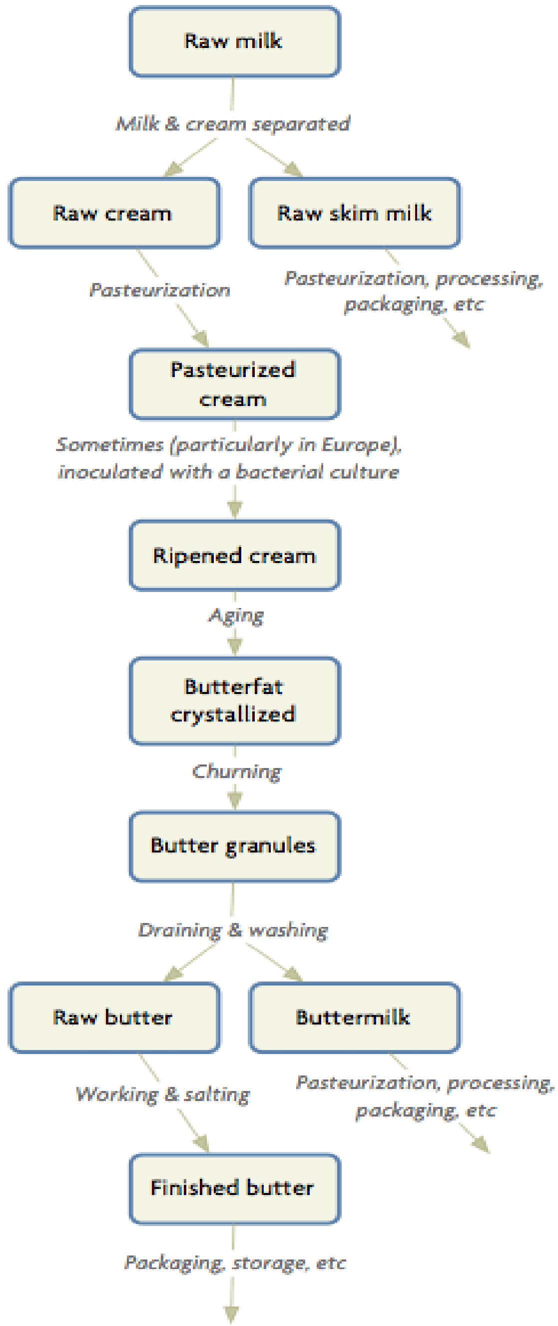

Figure 3 Buttermaking block flow diagram

Milk and Cream Separation:

As aforementioned the raw material for butter is milk, which is collected from cows. For other types of butter the milk would come from different animals such as goat, ewe, and mares. The production facility may obtain the cream by fluid milk dairy that is supplied or separating it themselves from whole milk. If this separation is done by the butter manufacturer, the whole milk is preheated to the required temperature in a milk pasteurizer before being passed through a separator [2]. After milk is let to sit for days, cream is separated from the milk. It is usually done through a centrifugation process, where it is used to clarify the milk to remove solid impurities and skim the milk to separate the cream from skim milk. The most common unit used is a disk centrifuge that has self cleaning in place, which allows the separation/clarification process to happen in the same unit and hence makes it continuous. After the separation the skim and cream streams are recombined to a specified fat content i.e. standardized. A diagram of this process is shown in Figure 4.

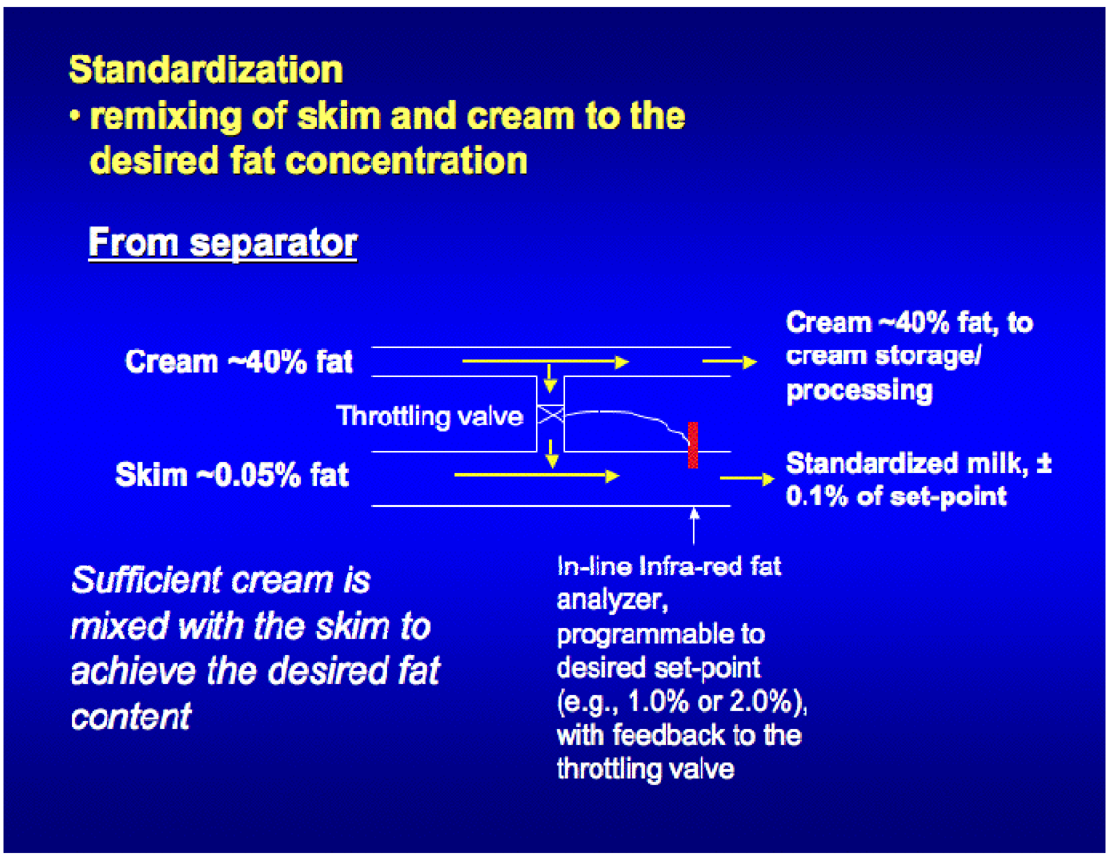

Figure 4 Standardization of skim milk and cream

Pasteurization:

Cream is pasteurized at a temperature of 95 °C or more to destroy enzymes and micro-organisms. This process would ensure that no organism would impair the quality of the butter.

Ripening:

If this step is required for the production of cultured butter, then the cream is mixed with cultures of *S. cremoris, S. lactis diacetyl lactis* and *Leuconostocs*. The cream is allow to ripened to a pH of 5.5 at 21 ºC and then to pH 4.6 at 13 ºC. This is done because most flavor development occurs between this pH range. Flavor development occurs at a higher rate during colder ripening stages. It should be noted that ripened butter does not usually go through washing or salting.

Aging:

In the aging tank, the cream is subjected to a program of controlled cooling designed to give the fat the required crystalline structure. The program will determine the consistency and composition of the butter. Cream is then held at cool temperatures for 12 – 15 hours to crystallize the butterfat globules, ensuring proper churning and texture of the butter. From the aging tank, the cream is heated to a required temperature before it is pumped to the churning step [2].

Churning:

Cream is churned either continuously (Figure 5) or in a batch, where the cream is agitated to break down the fat globules. That process causes the fat to form butter granules, they eventually grow larger, and then coalesce. In the end, there are two phases left: a semisolid mass of butter and the liquid left over, which is the buttermilk.

Draining and Washing:

The buttermilk is then drained from the butter granules. The butter granules are further worked to a continuous fat phase texture containing a finely dispersed water phase. After this step there used to be a washing step to ensure the removal of residual buttermilk, however, this is rarely done today.

Working and Salting:

Salt could be added to improve flavor and prolong its shelf-life as it can act as a preservative. In a batch process, salt is simply spread over the surface of the butter with a 1-3% concentration. If a continuous process is used, a salt slurry is added to the butter instead. The salt is dissolved in the aqueous phase to yield an approximate 10% salt concentration in water. Thereafter the butter is worked to ensure a homogenous blend of butter granules, water and salt.

Packaging and Storage:

The butter is finally patted into shape and then wrapped in waxed paper and then stored in a cool place. As it cools, the butterfat crystallizes and the butter becomes firm.

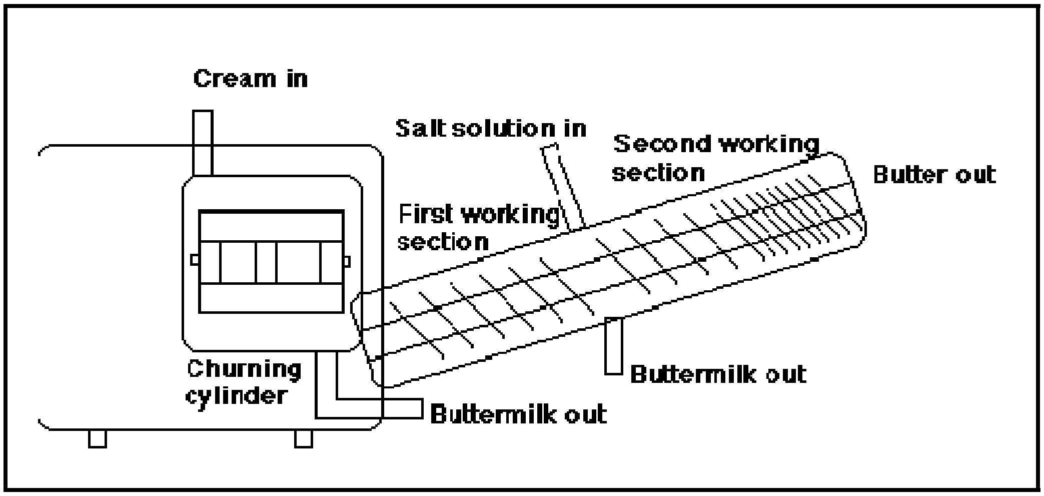

Figure 5 Continuous Flotation Churn

3.4. *Emissions, Disposal and Recycling*

3.4.1. Solid Wastes

Solid wastes that are produced in the dairy industry are mainly the sludge that results from wastewater treatment facilities. The amount of sludge will vary depending on the design of each system. However, literature values indicate that sludge production is roughly 0.5 kg per kg of removed COD for an aerobic system whereas 0.1 kg per kg of removed COD is produced for an anaerobic system [23]

Another source of waste may come from the packaging section of the process. Breakage or packaging mistakes will happen in a daily production. Improperly packaged butter will often be reprocessed; however, the packaging material is usually discarded. This type of waste generation is hard to quantify as it will depend on the occurrences. For this project, it will be assumed that about 5% of the packaging material will go to waste without leaving the cradle.

3.4.2. Wastewater

The main source of wastewater in the butter production is in the washing steps. These will clean the process equipment and maintain hygiene standards in work areas. This water usually contains buttermilk and some residual fats. If a continuous butter production process is used, particular to this case study, then the potential waste load is reduced by eliminating the buttermilk production and the washing steps [23]

The organic pollutant content of effluents is commonly expressed as the 5-day biochemical oxygen demand (BOD_5) or as the chemical oxygen demand (COD). According to literature, one liter of milk is equivalent to approximately 110,000 mg BOD5 or 210,000 - mg COD. After the dairy production processes the water effluent might contain about 2000 mg/L of BOD_5 and about 379 mg/L BOD_5 for butter production. In British Columbia, the effluent discharge limits (BC Dairy) are 45 mg/L for BOD_5. Thus, the facilities would treat their effluent accordingly before discharging to the appropriate water bodies. Other characteristics of the effluent are the fluctuation of pH and temperature, which also have to be treated. Inorganic contents of the water effluent may include phosphorous and nitrogen these values can be found in Table A – 8 in Appendix A.

The ranges that are given in literature indicate that the production of wastewater is highly influenced by management practices [14]. The source of each water waste depend on the management practices. It is indicated in literature that the major contribution to the waste load originates from cleaning operations, which takes place throughout the production process.

3.4.3. Air Pollution

The major source of air pollution in a butter production facility is caused by the need of energy. Green house gases such as CO_2, CO, NO_x and SO_2 are discharged as a result of the process. The following table gives a summary of the air emissions resulting from gas and oil combustion in a characteristic dairy plant.

Table 1 Air Emissions resulting from gas and oil combustion

Process:	Air emission (kg/ton processed milk)	
Heating by burning gas or oil	CO:	0.03
	CO_2:	92
	No_x:	0.1
	SO_2:	0.05
Producing milkpowder	Fine dust:	0.39
Cleaning	VOC:	0.05

For processes such as the ripening, aging and storage where refrigeration systems based on chlorofluorocarbons (CFCs) and NH_3 are required, fugitive losses of such gases might result from leakage and stripping of chilling machines when out of use. These have important environmental considerations as CFCs are recognized to be a cause of ozone depletion in the atmosphere. This type of emission could be prevented or reduced by changing the type of refrigeration used to a non- or reduced CFC system. Values of CFC emissions are not available at this moment but can be assumed to be similar to

Saputo indicated that they used electricity and fuel to power the processes [11]. According to literature, approximately 80% of a plant's energy needs are met by the combustion of fossil fuels, such as natural gas, to generate steam and hot water for evaporative and heating processes (i.e. Pasteurization). The rest is met by electricity to run electric motors (Continuous churn), refrigeration and lightning. It is also indicated that about 0.71 GJ/tonne of butter produced is consumed by electricity and 3.53 GJ/ tonne of butter produced is consumed by fossil fuel [5]. The equivalent CO_2 emissions that result from the butter production are 1.64 tonnes per year.

3.4.4. Noise Pollution and Hazardous Wastes

The constant noise generated by the processing equipment may become a nuisance to the neighboring residential areas. Also, the constant traffic generated by the transportation back and fro to the plant is unavoidable due to the regular delivery of cream, packaging, and shipment of product. These affect the general perception of the public to the company and may be reduced with technology improvement.

The hazardous wastes in these production facilities may consist of the oily sludge from gear boxes of moving machines, laboratory wastes, cooling agents, oily paper filters, batteries, paint cans among others. These are either incinerated or dumped. Some companies may opt to sell of give these to waste collection companies that will recycle or reuse them when appropriate. This method reduces their waste costs.

3.5. *Human Health Impacts*

Compared to alternative spreads, butter is one of the few that is minimally processed. As aforementioned, it contains a range of 'fat-soluble' vitamins that play an essential role in the body. For example, vitamin K is important of the health of the bones and teeth.

Butter is also rich in specific fats with a 80% fat, 20% water and solids composition. These may nourish the digestive tract and protect the gut from infections, and are essential for the manufacture of hormones in the body. However, butter, as an animal fat, contains both saturated fats and cholesterol - the two dietary ingredients that give rise to our blood cholesterol. Saturated fats, mainly found in animal products, can raise LDL (low density lipoprotein) cholesterol (the bad cholesterol) and the HDL (high density lipoprotein) cholesterol (the good cholesterol), thus it may raise the total blood cholesterol. Natural occurring cholesterol in butter, on the other hand, has little effect on blood cholesterol in most people. But for some, even a little dietary cholesterol can cause a soar in blood cholesterol levels.

4. MARGARINE

4.1. *Introduction*

Vegetable oil from canola, palm, sunflower, rape seed, olive, corn and soybean oils are used to make margarine. The oil is removed from either seeds or beans by either expulsion or extraction. The crude oil is neutralized to remove any free fatty acids to prevent unpleasant taste from developing. The neutralized oil is then washed and dried thoroughly. It is then bleached using a special absorbent earth to remove any colour or impurities. After oil modification has been completed, the oil is deodorized to remove any smells and tastes. This process is completed by blowing steam through the heated oil, where the steam and any smells and tastes are drawn off by a vacuum. At this stage the oil is now colourless, odourless, tasteless and a light brown colour. It is this oil that is bottled and sold as vegetable oil. The vegetable oil is then used in the manufacture of margarine and spreads.

Margarine used in UBC Food Service is mainly for cooking and baking, such as making sandwiches because it is considered as healthier than butter. However, it is not used in making the most famous UBC food product – cinnamon buns because of its taste.

4.2. *Manufacturing Process and Packaging*

The refined oils are the major ingredients for producing margarine and they are mainly generated by extracting and refining the trees, crops, oilseeds, fish oils and animal fats and mixing the liquid vegetable oils and fats with different proportions. The vegetable fats are hard but are not widely available; thus, vegetable oil modification is essential.

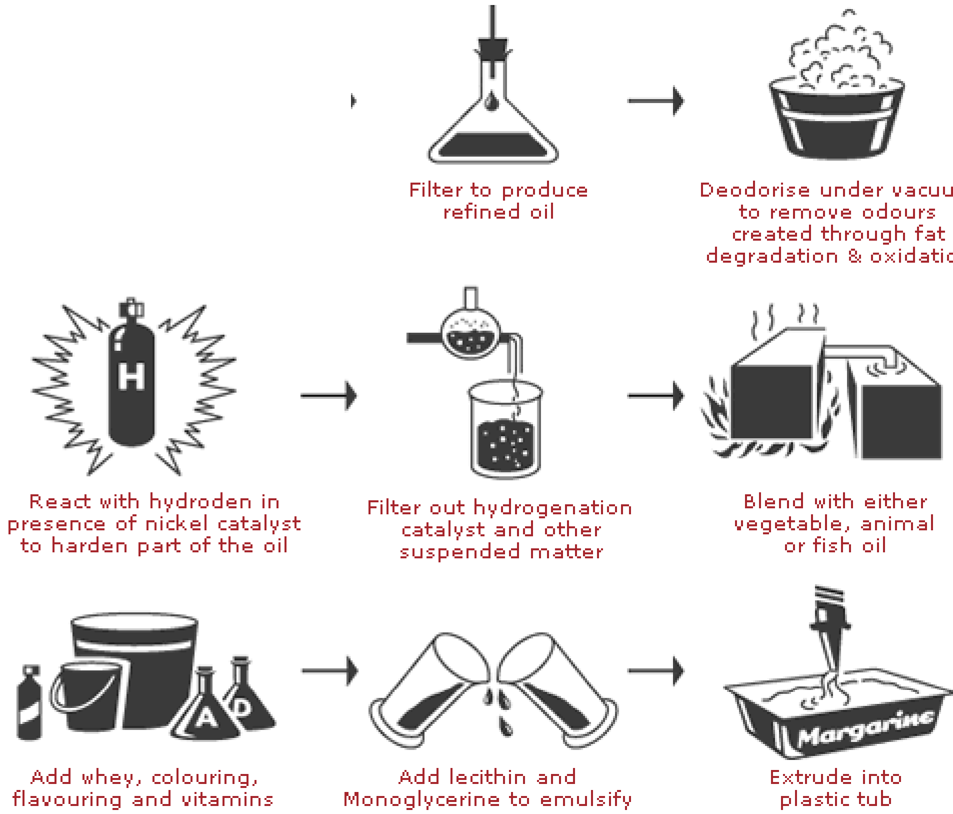

Figure 6: Simplified Process Flow Diagram for Margarine Manufacturing and Packaging

Oil modification is used to help make the vegetable oil harder. Three ways to modify oils are hydrogenation (hardening) – the most common, rearrangement (inter-esterification) or fractionation (separation). For the process of hydrogenation, the oil is reacted with hydrogen under pressure and at high temperature. Because both hydrogenation and rearrangement processes are quite slow, nickel catalyst is added into the processes to saturate the carbon double bonds so that the product is harder. The catalyst and any suspended matter are then filtered out of the mixture before the final products are stored. The mixture is next blended with either vegetable, animal, or fish oil to obtain the right texture, and then flavouring, colouring, vitamins, and emulsifiers are added. The emulsion is pasteurized at temperatures around 70 to 86 ^{o}C, and after chilling, the product is ready to be packed into plastic tubs, packets and cases and kept chilled for storage at 2 to 5 ^{o}C and transported to supermarkets and warehouses.

Margarine is usually stored in plastic tubs. After the margarine is consumed, the tubs can be either recycled or used for other storage purposes (as practiced at UBC).

Figure 7: Different Packaging of Margarine

4.3. *Emissions, Disposal and Recycling*

4.3.1. Solid Wastes

The major sources of solid waste from margarine manufacturing process are product losses and packaging, similar to the manufacturing process of butter. It is assumed that the product loss is about 10 vol% of the total production because it does not meet the quality control standard. Similar to butter production, packaging generates waste, such as the packaging material discarded, because of the rupture of packaging happened in the production process. However, it is important to note that different margarine manufacturing plant may have different product loss percentage because the loss is always unexpected; therefore, for this project, it will be assumed the product material waste is 10 vol% of the total production.

4.3.2. Wastewater

In margarine production, most of the wastewater is generated during the washing process. It consists of fat, oil and grease (FOG) which comes from the raw materials, seeds oils. Because the location of the margarine plant generated for the UBC Food Service is not available, it is estimated that the COD and BOD_5 for the wastewater generated from the margarine manufacturing plant are approximately 800 mg/L and 400 mg/L, as shown in Table A – 7. The FOG residues produced can be transported to another process in the same plant (on-site recycling) or other wastewater treatment processes, such as processes with membrane bioreactor for bio-treatment.

4.3.3. Air Pollution

The major source of air pollution in a margarine production process is produced during the extraction of canola oil. The pollutants consist of mostly organic compounds, as summarized in the following table:

Table 2: Emission from Margarine Process

Compound	%wt
Ethanol	20
Other alcohols (e.g. propanol)	10
Aldehydes (e.g. acetaldehyde)	20
Sulphur Compounds (e.g. dimethylsulphide)	10
Carboxilic acids (e.g. pyruvic acid)	10
Alkanes	10
Aromatics	10
Ethers	10
Total	100

4.3.4. UBC Food Services

Most grease is the by-product of cooking in the restaurants of UBC Food Service. Oils and greases are washed into the kitchen sinks and food drains, and thereby, they would clog the sewers eventually by sticking the inner sides of the sewer pipes of the buildings or even in the streets. This would also cause the sewage overflows, or even flooding during the raining days. Using chemicals such as soaps and detergents can be useful to dissolve the grease but one needs to be cautious because sometimes the grease can be passed down to the pipes, clogging sewer pipes in another area.

Figure 8: Grease Buildup Inside Sewer Pipes

Composting of organic waste, grease, oil and fat is one of the effective waste reduction methods. It is suggested that the grease waste can be stored in an unused soda container to let the grease cool down in order to become slightly solid and toss the container for composting. Within the UBC campus, the recycled cooking oils from the restaurants can be used as biodiesel fuel, which can be sent to the Environmental Youth Alliance UBC.

Because the margarine produced are stored in tubs, which cannot be recycled or disposed of with the regular trash, it is important to reuse the margarine containers for other usages, such as storing other food.

4.4. *Human Health Impacts*

Margarine consists of same composition as butter. The hydrogenation process in the manufacture of margarine "solidifies" liquid vegetable oil into a spread so it is easier to use. Its advantage over butter is that it does not contain saturated fats. However, as a result of hydrogenation trans-fats are produced. Similar to saturated fats, trans-fats also increase LDL cholesterol (the bad cholesterol) and lower HDL cholesterol (the good cholesterol). This is most problematic for people with high fat diets. In recent years, food manufacturers and the general public began to realize the negative health effects of trans-fats. Another type of margarine is now widely available - non-hydrogenated margarine. This type of margarine contains no trans-fat and is softer than the first-generation margarine stick. Instead of hydrogenating the liquid vegetable oil, manufacturers now add a tiny amount of modified palm and palm kernel oil to enhance spreadibility of margarine. Other technologies such as using supercritical fluids for hydrogenation are being adopted, such that we may be able to enjoy the benefits of partially hydrogenated oils without the trans fats [4].

5. ENVIRONMENTAL IMPACTS

The goal of Life Cycle Analysis (LCA) is to compare the environmental performance of products and services, in order to choose the least burdensome one. For this LCA, some categories of assessed damages are global warming (greenhouse gases), acidification, smog, and ozone layer depletion.

The greenhouse effect describes a natural phenomenon – the capability of certain gases in the atmosphere to trap heat emitted from the Earth's surface. The effect provides insulation for the Earth's surface, without which, the environment would become too cold for most living organisms to survive. In recent decades, it has been observed that the average temperature of the Earth's near-surface air and oceans has been increasing. This increase in temperature and its projected continuation is global warming, which leads to climate change and the survival of many species. Although CO_2 is the most important greenhouse gas and is the largest emission from a system, quantifying the total amount of greenhouse gases produced is the key to examining the global warming potential (GWP) of the system.

The boundary of the LCA greenhouse gas emission calculation extends from the raw material acquisition for both butter and margarine, to the manufacture of the products, and eventually, to the transportation of the products to the client (UBC). Table 3 shows the total GHG emission based on the consumption by UBC for butter and margarine, respectively, and also the detailed breakdown of the contributions from each stage of the products' life time.

The large amount of emission for butter at the raw material stage is primarily due to the methane produced by the cows' burping and flatulence. An average cow produces 600 L of methane gas per day; methane gas has a GWP of 21, which means that 1 kg of methane gas has the same potential of global warming as 21 kg of CO_2. The large emission for the butter transportation is due to the fact that one of the butter suppliers getting the product from

Red Deer, AB, hence increasing the food miles, fuel costs, and GHG emission. From these data, it is determined that for every kilogram of butter or margarine consumed on the UBC campus, the GHG emissions are 27.3 kg and 20.7 kg, respectively.

Table 3: Greenhouse Gas Emission during the Products' Life Cycles

	Unit	Butter	Margarine
UBC Consumption	kg/year	5725.56	2317.79
GHG Emission - Raw Material	ton eq CO2/yr	42.56	2.51
GHG Emission - Manufacture	ton eq CO2/yr	1.64	0.36
GHG Emission - Transportation	ton eq CO2/yr	112.34	45.12
Total GHG Emission	ton eq CO2/yr	156.54	48.00

Acidification describes the forming of acid precipitation (acid rain) when nitrogen oxides (NO_x) and sulphur oxides (SO_x) are emitted to the atmosphere and absorbed by water droplets in the cloud. The acidified droplets fall to the ground in forms such as rain and snow, increasing the acidity of the soil and affecting the chemical balance of water bodies. The heating process of milk in the butter production emits a considerable amount of both NO_x and SO_x.

Ozone depletion is the slow and steady decline in the amount of ozone in the Earth's stratosphere. A more prominent phenomenon is the formation and enlargement of the ozone hole in the stratosphere over Antarctica. A main contributor to ozone depletion is chlorofluorocarbons (CFCs), which can be leaked from refrigeration systems in the butter manufacture processes such as ripening, aging, and storage.

Vegetable oils such as canola oil are the main ingredient for the manufacture of margarine. When canola oil is extracted from canola seeds, considerable amounts of volatile organic carbons (VOCs) and aldehydes are emitted to the air from the process. These chemicals are highly reactive and oxidizing. They are the main contributors to the formation of photochemical smog near urban areas, which would then lead to many serious health problems.

6. ECONOMIC ANALYSIS

As observed from the Canadian market share of butter, margarine and other fats and oils (table below), butter still holds more market share than margarine. In recent years, however, the sales volume of animal fats such as butter and cooking fats (e.g. lard) has been steadily declining, while the sales of vegetable-based alternatives are either stable or increasing. This is partly due to the general public's perception of butter being high in fat, and also partly due to the increase in retail price of butter.

Table 4: Canadian Market Share (%) for Butter and Other Fats and Oils (based on retail sales volumes)

	2001	2002	2003	2004	2005
Butter	18.8	18.8	18.5	18.1	17.5
Margarine	5.3	5.3	5.3	5.3	5.3
Olive Oil	2.9	2.9	3.0	3.0	3.1
Vegetable and Seed Oil	29.5	29.5	29.7	30.1	30.3
Cooking Fats	3.3	3.2	3.1	3.0	2.9

Source: Euromonitor, calculations done by AAFC-AID, Dairy Section

6.1. *Butter*

Currently the total consumption of butter on the UBC campus is 5725.56 kg per year. For three main varieties of butter, regular bulk, individual sized, and whipped, the usage is 2684.69 kg, 624.88 kg, and 2415.99 kg, respectively; the cost is $8.36, $11.03, and $21.80 per kg, respectively. The total cost of butter purchased by the UBC Food Services is $82001.65 per year.

6.2. *Margarine*

Currently the total consumption of margarine on the UBC campus is 2317.79 kg per year. The cost is approximately $1.87 per kg for the regular bulk variety, which is significantly less expensive than its butter counterpart. The total cost of margarine purchased by the UBC Food Services is $4329.61 per year.

Regarding whether or not margarine could replace butter, the only possible substitution at this time is the regular bulk variety due to usage. If the regular bulk butter were replaced with margarine, the total annual cost of butter and margarine would decrease 20.18%, a saving of nearing $2,000.

Table 5: Savings from Replacing Butter with Margarine

	Price/kg	Mass (kg)	Current Cost	Cost (margarine subs. regular butter)
Regular bulk	8.36	2,684.69	22439.57	5014.98
Individual Sized	11.03	624.88	6894.19	6894.19
Whipped	21.80	2,415.99	52667.88	52667.88
Margarine	1.87	2,317.79	4329.61	4329.61
		Total Cost	$86,331.26	$68,906.66
			Savings	20.18%

In addition, butter storage requires refrigeration, whereas margarine storage does not. More savings would be possible from reduction in electricity usage if butter were substituted with margarine.

7. Conclusions

Having evaluated the environmental impact and economics of butter and margarine, conclusions can be made. With the client being UBC, the impact on the environment of butter, is far greater than that of margarine. The cost of margarine is significantly cheaper than butter. Both assessments point to margarine being the better choice over butter. In addition, butter is found to be worse for human health as it contains more cholesterol and saturated fat than margarine. However, there are uncertainties to the life cycle analysis. For example, there is a lack of emission data for certain wastes generated, which leads to an incomplete compilation of the total emission. As well there is uncertainty on the allocation of methane emission for butter, when other dairy products (e.g. milk, cheese, cream) are produced in the same process. Overall, based on available quantitative and qualitative findings, it is concluded that margarine is the more recommended choice over butter.

8. RECOMMENDATIONS AND OTHER CONSIDERATIONS

Although the results point to margarine as being more benign to the environment than butter, there are a few things that need to be further explored before making the conclusion definite. It should be noted that this study did not take into consideration:

1. The emissions from the raw materials extractions are limited to CO_2
2. Quantification of environmental impacts such as: smog formation potential, acid rain potential, and ozone depletion.
3. Health impacts of the emissions from the production plants.

Hence, for future studies it would be beneficial to determine the previous parameters to have a complete picture of the impacts of these table spreads.

From the present study it was observed that 72% of the CO_2 emissions for butter production were due to transportation of the product. In order to reduce the food miles, it is recommended that UBC Food Services consider the use of local organic butter for a portion of their cooking activities. An alternative could be the in-house production of organic butter in the UBC farms if the space is available. This option would not only decrease the food miles of butter but would also take UBC closer to being a self-sustained community. An in-depth economical analysis of this project could be carried out to determine the feasibility of this project. UBC could also partner with a local butter production to provide UBC with its yearly requirement of 5.7 tonnes.

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Appendix A – Figures and Tables

Table A- 1 Physical Properties of Milk fat and Butter

Property	**Units**	**Value**
Fat content	Wt%	80
Size of fat globules	μm	1-20
melting point of milk fat	^{o}C	31-36
solidification of milk fat	^{o}C	19-24
apparent specific heat	kJ/(kg.KA)*	
at 0 ^{o}C	^{o}C	2.14
15 ^{o}C	^{o}C	2.2
40 ^{o}C	^{o}C	2.32
60 ^{o}C	^{o}C	2.42
density of milk fat	g/cm3	
at 34 ^{o}C > mp	g/cm3	0.91-0.95
60 ^{o}C	g/cm3	0.896
viscosity of milk fat, mPa.s	mPa.s (=cP)	
at 30 ^{o}C	mPa.s (=cP)	25.8
50 ^{o}C	mPa.s (=cP)	12.4
70 ^{o}C	mPa.s (=cP)	7.1
viscosity of butter at 21oC	mPa.s (=cP)	3.10E+05
iodine number,normal butter		30.5
melting point of butter	^{o}C	33.3
Spreadability		
at 21 ^{o}C		Good
7-6 ^{o}C		Desirable
4 ^{o}C		Difficult
Ratio of firmness to butter firmness of butterfat		
Summer		1.97:1
Winter		1.48:1
Coefficient of expansion of liquid pure butter fat (30 -60 oC)		0.00076
Free acidity, fresh butterfat		0.05 - 0.1 %

Table A - 2: Physical Properties of Margarine

Property	Units	Value
Fat content	Wt%	>80
Size of fat globules	□ m	1-20
melting point of milk fat	^{o}C	33-43
solidification of milk fat	^{o}C	22-25
density of milk fat	g/cm3	0.918-0.925
viscosity of butter at 20oC	mPa.s (=cP)	1+05-2+05
Spreadability		
at 20 ^{o}C		Good
5 ^{o}C		Desirable
4 ^{o}C		difficult
Ratio of firmness to butter firmness of butterfat		
Summer		1.97:1
Winter		1.48:1
Coefficient of expansion of liquid pure butter fat (30 -60 oC)		0.00076
Free acidity, fresh butterfat		0.05 - 0.1 %

Table A – 3: Fat Type per Serving of Butter and Margarine

Product	Total Fat	Saturated Fat	Trans Fat	Saturated and Trans Fats
Butter	10.8	7.2	0.3	7.5
Margarine, stick (82% fat)	11.4	2.3	2.4	4.7
Margarine, stick (68% fat)	9.5	1.6	1.8	3.4
Margarine, tub (80% fat)	11.2	1.9	1.1	3.0
Margarine, tub (40% fat)	5.6	1.1	0.6	1.7

Table A - 4: Greenhouse Gas Emission of Products during Manufacturing

Product		Butter	Margarine
Production Rate	kg/yr	5725.56	2317.79
Fuel Consumption	GJ/tonnes product	3.53	2.15
Energy consumed by gasoline*	GJ/yr	20.21	4.98
eq CO2 release from gasoline combustion	kg eq CO2/GJ	69.30	69.30
eq CO2 release	kg eq CO2/yr	1400.64	345.34
GHG Emissions from fuel	ton eq CO2/yr	1.40	0.35
Electricity Consumption	GJ/tonnes product	0.71	0.14
Energy Consumed by electricity	GJ/yr	4.07	0.32
eq CO2 release from electricity**	kg eq CO2/GJ	58.60	58.60
eq CO2 release	kg eq CO2/yr	238.22	19.02
GHG Emissions from electricity	ton eq CO2/yr	0.24	0.02
Milk production	L/yr/cow	8839.00	
Number of cows	cow	12.96	
Production yield	L milk/kg butter	20.00	
Volume of milk per year	Lmilk/yr	114511.27	
Cow's methane production	L/day/cow	600.00	
Cow's methane production	kg/day/cow	0.43	
CH4 emitted by cows per year	kg CH4/yr	2026.57	
GWP factor	kg eq CO2/kg CH4	21.00	
Equivalent Cow CO2 emissions	kg eq CO2/yr	42557.93	
Equivalent Cow CO2 emissions	ton eq CO2/yr	42.56	
Production yield margarine	kg mar/kg oil		0.60
Oil needed per year	kg oil/yr		3862.98
Oil yield from seeds	kg oil/kg crop		0.30
Harvest Lost			0.50
Mass of canola crop needed	kg crop/yr		25753.19
Fuel consumption per tonne canola crop	L diesel/tonne canola		35.02
Volume diesel used per year	L diesel/yr		901.88
Density of Diesel	kg/L		0.85
Mass of diesel used per year	kg/yr		768.40
Diesel LHV	kJ/kg		42000.00
Energy consumed by process	kJ/yr		32272759.95
eq CO2 release from diesel comb	kg CO2 /kWh		0.28
eq CO2 release from diesel comb	kg CO2/kJ		7.78E-05
Equivalent diesel CO2 emissions	kg eq CO2/yr		2510.10
Equivalent diesel CO2 emissions	ton eq CO2/yr		2.51
Total GHG Emissions	ton eq CO2/yr	44.20	2.87

Table A – 5: GHG Emission of Products during Transportation

Description	Units	SYSCO VANCOUVER	SAPUTO A	SAPUTO R	Total Saputo	NEPTUNE
Total Distance Travelled	km/trip	**156.1**	**137.3**	**1184.9**	**361.0**	**99.9**
From Farm to Plant	km/trip	53.4	53.4	60.0	54.8	53.4
From Plant to Vendor	km/trip	60.0	60.0	1101.0	282.3	16.4
From Vendor to UBC	km/trip	42.7	23.9	23.9	23.9	30.1
Total Number of Trips	trips/year	468	520	312	476	468
From Farm to Plant	trips/year	208	208	104	186	208
From Plant to Vendor	trips/year	208	208	104	186	208
From Vendor to UBC	trips/year	52	104	104	104	52
Total distance in year	km/yr	51615.2	52145.6	246459.2	93639.6	32167.2
Fuel Consumption	L/km	0.4	0.4	0.4	0.4	0.4
Volume of Gasoline consumed	L/yr	20762.2	20975.6	99138.2	37666.5	12939.3
Density of Gasoline	kg/L	0.7	0.7	0.7	0.7	0.7
Mass of Gasoline consumed	kg/yr	14533.5	14682.9	69396.7	26366.6	9057.5
Gasoline LHV	MJ/kg	44.8	44.8	44.8	44.8	44.8
Energy Used for transportation	MJ/yr	651103.0	657793.8	3108974.4	1181222.5	405775.1
CO2 release	kg/GJ	69.3	69.3	70.3	71.3	69.3
CO2 release for trans.	eq CO2 kg/yr	45121.4	45585.1	218560.9	84221.2	28120.2
GHG Emissions	eq CO2 ton/yr	45.1	45.6	218.6	84.2	28.1

Table A - 6: UBC Butter and Margarine Usage Information

VENDOR	PRODUCT	SIZE	unit of size	UNIT	USAGE	PRICE/ UNIT	Total Price	Total Mass (kg)	Total per company (kg)	Mass % Distribution	Price per kg	Specific Uses
SYSCO VANCOU -VER	Margarine Soft (Canada)	20	lb	CS	4	14.83	59.32	36.29		0.45%	1.63	baking
	Margarine Soft	15	kg	CS	141	25.46	3,589.86	2115.00		26.30%	1.70	baking
	Margarine Garlic Spread	4.5	kg	CS	37	18.39	680.43	166.50	2317.79	2.07%	4.09	sandwiches
SAPUTO	Butter Regular	0.25	kg	250 gr	122	2.15	262.30	30.50		0.38%	8.60	sandwiches
	Butter Unsalted	0.25	kg	250 gr	3	2.53	7.59	0.75		0.01%	10.12	baking
	Butter Unsalted			lb.	825	3.74	3,085.50	374.21		4.65%	8.25	baking
	Butter Regular			lb.	2554	3.79	9,678.86	1158.38		14.40%	8.36	sandwiches
	Butter Regular - 25lb- 454 gm	25	lb	case	94	94.38	8,907.58	1070.25		13.31%	8.32	sandwiches
	Butter Patties 5lb 6.3 gm	5	lb	box	22	22.31	497.74	50.60		0.63%	9.84	catering
	Butter Cups 715 count - 5 Kg	5	kg	case	54	43.02	2,323.94	270.10		3.36%	8.60	residences and retail locations
	Whipped Butter Cups 715 count - 3.3 Kg	3.3	kg	case	108	42.51	4,570.25	354.78	3309.57	4.41%	12.88	residences and retail locations
NEPTUNE	Butter Patties Salted (72 per lb)	5	lb	5 lb	169.32	46.35	7,847.98	384.01		4.77%	20.44	catering
	Butter Whipped	5	lb	5 lb	895.95	50.03	44,819.90	2031.98	2415.99	25.26%	22.06	sandwiches?
Total							$86,331.26	8043.35		100.00%		

Table A – 7: Waste Emissions

Parameter	Unit	Discharge Limit	Butter Plant	Margarine Plant
TSS	mg/L	45	253	130
BOD5	mg/L	45	379	417
COD**	mg/L	45	506	797
Effluent Capacity, >	m3/d	50	50	50
Sludge formation	kgTSS/kg COD removed		0.5	0.5

*assume anaerobic system

**BOD5 may be replaced with COD acc. to regulations

Table A – 8: Danish Dairy Processing Survey 174 companies: average 1.3 m3 effluent/tonne milk processed

Parameter	Unit	Average Dairy	Butter	Margarine
COD	mg/L	2000	506	797
BOD_5	mg/L	1500	379	417
FAT	mg/L	150	38	50
Total Nitrogen	mg/L	100	25	30
Total Phosphorous	mg/L	30	8	14

Appendix B – List of Abbreviations

BOD	Biological oxygen demand
CFC	Chlorofluorocarbon
COD	Chemical oxygen demand
FOG	Fat, oil and grease
GHG	Greenhouse gas
GWP	Global Warming Potential
HDL	High density lipoprotein
LCA	Life cycle analysis / life cycle assessment
LDL	Low density lipoprotein
STD	Standard temperature and pressure
TSS	Total suspended solids
UBC	The University of British Columbia
VOC	Volatile organic carbon