

CHAPTER II

LITERATURE REVIEW

2.1 Animal Fats

There are two sources of land animal derived lipids that are commonly consumed in diet: the first one is lipids from animal body tissues, commonly referred to as animal fats or meat fats, and the second one is from milk lipids. The origin and means of obtaining lipids from body tissues and milk as well as their composition and characteristic, differs. Furthermore, due to their common animal origin, animal lipids often share a similar public perception and image. This image and the role of land animal derived lipids in human nutrition seem somewhat inconsistent. In a historical context, meat fats and, later on, milk lipids were for long the only readily available and highly appreciated source of fats that was available in substantial amounts for human nutrition, and had been traditionally used as ingredients in food.

“Animal fats” or “meat fats” is a technical term which actually refers to fats obtained from adipose tissues of land animals by a process called rendering (Love, 1996). At one time, animal fats also served purposes other than food, eg. as fuels for torches (and later candles), cosmetics, and even as early oleochemicals for lubricants and soaps (Dugan, 1987). The Celts are known to have manufactured soap from boiling animal fats with ashes, and they probably transmitted their knowledge of fat processing to the Romans. The variety of uses of rendered animal fats grew into manifold areas, and impressive list of non-food uses of animal fats or fatty acids produced therefore is given by Dugan (1987). The major edible animal fats are tallow, derived from the ruminants species (mainly cattle but also sheep and goat), lard, which is derived from pigs, and poultry fats, derived from poultry offal.

In contrast to plants, fat is found throughout all tissues in animal organisms, although there are specific sites where fat is preferentially stored as so-called depots when meat animals are continuously fed above energy maintenance levels (Wood, 1990). Fat is typically deposited in the abdominal cavity, partially around the kidneys and the

stomach, peripheral areas under the skin (subcutaneous adipose tissue), between muscles and bones (intermuscular fat) and within skeletal muscles (intramuscular fat). In the muscles, lipids are also present as intracellular lipid droplets (particularly in red fibers) and in the form of phospholipids as important components of cell membranes (Wood, 1990).

2.1.1 Animal Fats In Food

Rendered or processed animal fats fit for human consumption have been traditionally used as shortenings in baked foods, spreads and margarines and deep-frying fats in the food industry or the catering business as well as in private households. Traditionally, yellow grease acquired by renderers from food service establishments was of animal origin (Kiepper, 2001). Although they are still commercially offered for these purposes, the use of animal fats in food has declined. The major parts of rendered animal fats is currently used in the production of livestock feeds, cosmetic and industrial oils, and fats for producing fuel, lubricants and soaps. Only 10 % of the 2.77 million tones of animal fats Europe were used as food in 2002 (Woodgate, 2004). In 2003 the amount of animal fats produced decrease slightly to 2.6 million tones and the proportion used for food fell considerably to 6 %. This was below the amount used for pet food (7%). The share used as animal feed remained constant at 25 %. About 31 % was used for soap and oleochemicals and another quarter (24%) as energy substitute. According to figures from the US Census Bureau provided by the National Renderers Association (www.renderes.org), only a small and decreasing parts of edible tallow produced is actually consumed for edible use (from 17.3 % in 1998 to 11.8 % in 2004) in the USA. The proportion of lard consumed for edible uses increased in the same time from about 55 to 73 % but due to the overall decrease in lard production, the total amount of lard used for edible purposes declined from 135.9 to 84.2 kt. (FAO, 2008).

However, an important contribution to the intake of animal lipids is its consumption as part of meat and meat products. The contribution of fresh meat to the consumption of fat might nevertheless be over-estimated because fat lost during cooking and visible subcutaneous and intramuscular fat is often discarded on the plate (FAO, 2008). Cooking loss and leftovers can reduce the actual fat intake by 35 -65 % of the original

fat content of the raw meat (Sheared et al, 1998; Gerber et al, 2009). Processed meat products, in contrast, may contain a fair bit of added cutting fats, particularly from pork, and abdomen fat in the case of poultry, which is directly used in products like salami or frankfurter type of sausages.

2.1.2 Edible Beef Fat (Tallow)

Edible beef fat is obtained from bovine adipose tissues covering the abdominal cavity and surrounding the kidneys and heart and from other compact, undamaged fat tissues. The fat is light-yellow due to carotenoids derived from animal feeds, brittle in consistency and melts between 45 and 50 °C.

From beef fat, various commercial products can be prepared including *Prime Beef Fat*, obtained by melting fresh and selected fat trimmings in water heated to 50-55 °C. The acid value resulting from lipolytic action is not allowed to exceed 1.3 (corresponding to approx. 0.65 % free fatty acid). This beef fat when heated to 30-34 °C yields two portions: oleomargarine (liquid) and oleostearine (solid) (Belitz et al., 2009). Oleomargarine is a soft fat with a consistency similar to that of melted butter. It is used by the margarine and baking industries. Oleostearine (pressed tallow) has a high melting point of 50-56 °C and it is used in the production of shortenings. The authors (Belitz et al., 2009) have also mentioned that edible beef fat (secunda beef fat) is obtained by melting fat in water at 60-65 °C, followed by a purification step. Lower tallow quality has only industrial or technical importance, for example, as raw material for the soap and detergent industries (Hoffmann, 1989). Beef tallow has some physicochemical properties such as melting point, food energy, and iodine value and they are 42-45.6 °C, 3.774 K/J, 37-55 respectively (<http://www.welch-holme-clark.com>). The fatty acids composition of beef fat is shown in Table 1 (Haas, 2005) and the composition of edible fat triacylglycerols is given in Table 2 (Christie et al., 1986) and (Brockerhoff et al., 1966).

According to Table 2 (Christie et al., 1986), in beef tallow and chicken fat palmitic acid is located at all three positions of the triacylglycerol molecule in beef tallow and chicken fat. For beef and chicken fat, the percentage of palmitic acid at sn-1, sn-2, and sn-3 are

similar, with beef tallow at (41 %, 17% and 22 %), while, for chicken fat at (25 %, 15 % and 24 %) respectively.

In contrast, lard has the high proportion of palmitic acid at the sn-2 at (sn-1 10 %, sn-2 70 %, and sn-3 Traceamount). This has been exploited to develop a method to detect the adulteration of beef fat with lard (Thomas, 1987).

Table1: Average Fatty Acids Composition Of Some Animal Fats (weight-%)

Fatty acids	Beef tallow	Sheep tallow	Lard	Goose fats
12:00	0	0.5	0	0
14:00	3	2	2	0.5
14:1 (9)	0.5	0.5	0.5	0
16:00	26	21	24	21
16:1 (9)	3.5	3	4	2.5
18:00	19.5	28	14	6.5
18:1 (9)	40	37	43	58
18:2 (9,12)	4.5	4	9	9.5
18:3 (9, 12, 15)	0	0	1	2
20:00	0	0.5	0.5	0
20:02	0	0.5	2	
Other	3	3	0	0

Source: (Haas, 2005)

TABLE 2:Positional DistributionsOf Fatty Acids In Triacylglycerols Of Animal Depot Fats

Fatty Acids, mol%								
Animal Fat	Position	14:00	16:00	16:01	18:00	16:01	18:02	18:0 3
Pig	1	1	10	2	30	51	6	
	2	4	70	5	2	13	3	
	3		Tr	2	7	73	18	
Cattel	1	4	41	6	17	20	4	1
	2	9	17	6	9	41	5	1
	3	1	22	6	24	37	5	1
Sheep	1	1	35	2	47	4		
	2	4	14	2	15	52	5	
	3	3	16	1	42	26	2	
Chicken	1	2	25	12	6	33	14	2
	2	1	15	7	4	43	23	3
	3	1	24	12	6	35	14	3

Source: Christie., et al 1986
Tr: trace

2.1.3 Pig Fat (Lard)

Pig fat, or lard, is obtained from fat tissue covering the belly (belly trimmings) and other parts of the body. The back fat is mainly utilized for manufacturing of bacon. After tallow and butter, lard is currently the animal fat most consumed. It is influenced by the breed and feeding of pigs.

Lard was widely used in the cuisines of Europe, China, and the New World and still plays a significant role in British, central European, Mexican, and Chinese cuisines. In British cuisine, lard is used as a traditional ingredient in mince pies and Christmas puddings and for frying fish and chips, as well as many other uses. In comparison with

beef tallow, lard has almost same properties with beef tallow where the melting point is 30–40 °C, food energy 3770 kJ, and iodine value 45–75 (<http://www.welch-holme-clark.com>)

Scollan in (2001) illustrated that although a high proportion (about 90%) of 18:3n-3 in the diet of ruminants is normally hydrogenated in the rumen; some does escape to the duodenum, to be absorbed and deposited in tissues as in pigs. In addition, the proportions of long-chain PUFA are also similar between the species, apart from 20:4n-6 that is high in pigs because of the high concentration of its precursor 18:2n-6 (Rossell, 2001).

The study of Enser *et al.*, (1996) also included analysis of subcutaneous adipose tissue removed from the steak. Values for the proportions of the C12–C18 fatty acids were similar to those for muscle but whereas small proportions of the C20–C22 PUFA were present in pork, these were not detected in beef and lamb, acting the lack of incorporation of the long-chain PUFA into ruminant triacylglycerols (Enser *et al.*, 1991).

In contrast to the composition of triacylglycerols found in beef fat, lard contains fewer triacylglycerols of the type SSS and more of the type SUU, USU, and UUU (S: Saturated; U= Unsaturated fatty acids) (Brockerhoff *et al.*, 1966). As a consequence, lard melts at lower temperatures and over a range of temperatures rather than melting sharply at a single temperature, and its shelf life is not particularly long due to the rancidity phenomenon. In comparison with beef, hog depot fat contains the saturated fatty acids (C16:0) mainly in the position sn-2. This difference can be used in the detection of lard (Haas, 2005).

In 2005, Charlie Scrimgeour reported that because of the content of fatty acids in lard and pattern of acylglycerol structures, especially to a high content of acylglycerols with palmitic acid (16:0) in the sn-2 position. In lard, 72% of the residues at this site are palmitic acid, whereas this fatty acid constitutes only 10% of the residues at the sn-1 position and is found in only traces in the sn-3 position. On the other hand, Haas (2005)

reported also that the greater uniformity of lard triacylglycerol structures leads to a shorter plastic range and a sharper melting point. Larger crystals in the solid phase usually takes β form (Campos et al., 2002) ; and these are largely responsible for the poor creaming abilities and grainy mouth feel of lard (Scrimgeour, 2005).

Lard is unique among the common fats and oils in having a preponderance of palmitate at the sn-2 position, so, this has led to a unique use of this lipid such as human milk fat which also contains primarily palmitate at the sn-2 position of its acylglycerols. Lard has been employed in infant formulas in attempts to produce a products more closely resembling human milk (Kennedy, 2007, and Yang et al., 2003).

2.1.4 Chicken Fats

Chicken fat is fat obtained from chicken rendering and processing of animal adipose tissues. The total lipid concentration of raw skinless chicken (broiler) light muscle is approximately 1.7%. According to Haas (2005) light muscle lipids are composed of 36.6% saturated, 32.5% monounsaturated, and 30.8% polyunsaturated fatty acids. In addition, he added that the primary saturated fatty acids are palmitic acid followed by stearic acid. The major monounsaturated fatty acids are oleic and palmitoleic acids; linoleic acid, arachidonic acid (AA), and docosahexaenoic acid (DHA) are the primary polyunsaturated acids (PUFAs). All other fatty acids account for less than 1% of the total fatty acid concentration (Table 2).

Moreover, Kiepper in (2003) illustrated that the percentages of fatty acids are similar in light muscle with and without skin; the fat content is 6.7-fold as higher in muscle with skin (11.07 g/100 g of muscle). Therefore, the amounts of individual fatty acids in muscle with skin are higher than in muscle without skin for the same serving size. Rossell (2001) found that broiler chicken meat fatty acid composition was similar to that of pork, although the proportion of 18:2n-6 was much higher, that is, 18.9% against 9.5% in that study. Rule et al., (2002) also found a high value for chicken 18:2n-6 in a comparative study, 17.0% of total fatty acids where found in breast muscle. Among

other characteristic species differences is the very high value for 18:3n-3 in horse muscle and adipose tissue (Rossell, 2001; Robb *et al.*, 1972).

Table 2 illustrates that the distribution of the triacylglycerols in chicken fat is almost same as in beef tallow; where palmitic acid is located at all three positions of the triacylglycerol molecule. In the sn-2 position, 17 mol% is palmitic; at the sn-1 position, palmitic acid makes up 41%; and in the sn-3 position, 22% (Christie *et al.*, 1986; Brockerhoff *et al.*, 1966). According to different sources, chicken fat is characterized by melting point of 25–30 °C, food energy 3700kJ, and iodine value 70-79 (<http://www.welch-holme-clark.com>).

2.2 Analysis Of Fats

Four methods were used to analyze the fats content. These include Gas Chromatography (GC), High-Performance Liquid Chromatography (HPLC), Differential Scanning Calorimetry (DSC), and Fourier Transform Infrared (FTIR) Spectroscopy. These methods are discussed below.

2.2.1 Gas Chromatography

The GC is a robust technique for analysis of fats and oils. It has been much studied. This method involves partitioning of the components of lipid mixture on the vapor state between a mobile gas phase and a stationary nonvolatile liquid phase dispersed on an inert support (Casmir & David, 2008).

Analysis of fatty acid composition by GC usually requires derivatization of fatty acids to increase their volatility (Moreau, 1994). Fatty acids methyl esters (FAME) may be prepared by different transmethylation techniques, then separated on GC columns, and detected by flame ionization detection (FID). The gas phase for GC is usually nitrogen or helium for packed columns and helium or hydrogen for capillary columns. The identification of chromatographic peaks is based on comparison of their retention times with those of authentic samples (Casmir & David, 2008). GC analysis of TAG of food lipids may also provide information about positional distribution of fatty acids in the molecules. Naturally, occurring TAGs that are purified by TLC can then be resolved

without derivatization on the basis of their carbon number or molecular weight using capillary GC equipped with 8-15 m long columns coated with methylphenyl-, methyl-, or dimethylsilicone (nonpolar capillary). Use of helium or hydrogen as a carrier gas for separation of TAG on such columns requires higher temperatures than those employed for separation of methyl esters (Christie et al., 1994, and Takagi, 1990).

2.2.2 High –Performance Liquid Chromatography

High performance liquid chromatography (HPLC) is another powerful technique that is widely used for fats and oils analysis, especially in analysis of triacylglycerols (TAGs). Before the analysis, sample should be derived to facilitate the separation and to enhance the limit of detection for the HPLC analysis. In addition, it is advisable to do saponification for the sample to cut ester linkages and to get FFAs for their subsequent analysis. Fatty acids can be analyzed by forming 9-anthryl-diazomethan (ADAM) derivatives and employing a fluorescence detector. According to (Hayakawa et al., 1994), fatty acids increase their hydrophobicity when ADAM is bound to the carboxyl group; consequently, the derivatives are kept longer on a reversed-phase column than fatty acids and good separation is obtained. On the other hand, Evaporative light-scattering detection (ELSD) and FID - sometimes are called as universal detectors- have been wide use for detection of all types of lipids following HPLC separation (Kuksis, 1994, and Hammond, 1993).

Furthermore, normal phase HPLC column permits also the separation of normal chain and hydroxy fatty acid containing TAG. Normal phase HPLC column on silver ion-loaded anion exchange columns is currently used to resolve TAG based on their degree of unsaturation (Christie et al., 1991). Reversed phase HPLC (using C18 column) is also widely applied for separation and quantification of tri-, di-, and monoacylglycerols. Burkov & Henderson in (1991) have described that silver-ion HPLC can be employed to separate and identify conjugated linoleic acid isomers.

2.2.3 Differential Scanning Calorimetry

Differential scanning calorimetry (DSC) is a thermal analysis technique that has found many useful applications in both pharmaceutical and food research. In the field of food

research, DSC has found useful application in the study of physical and chemical proprieties of fats, carbohydrates, and proteins. The technique provides an effective tool for monitoring both the thermodynamic and kinetic proprieties of those food components in a variety of matrices (Nollet, 2004).

DSC has been used extensively to study the physicochemical proprieties of fats and oils. The chemical and physical proprieties of fats and oils are directly influenced by their composition of tri, di-, and mono-acylglycerols, fatty acid chain lengths, and degree of unsaturation. Most fats used in food industry exist in different polymorphic states. This polymorphic nature results from the different possibilities of lateral packing of fatty acid chains and longitudinal stacking of molecules in lamellas (Biliaderis, 1983). Fats undergo phase transitions during heat treatment (melting) and cooling (solidification, crystallization). These transitions involve the uptake or release of energy and are, thus, detectable by DSC. The characteristic melting and crystallization behavior of different fats makes it possible to use DSC to fingerprint their thermal behavior and detect adulteration.

DSC has some advantages over the more classical detection methods, as it is rapid and does not require sample preparation or solvent utilization (Chiavaro et al., 2008). The applications of DSC to the analysis and characterization of oils and fats for the determination of solid fat content, crystallization and melting profiles, enthalpy of transitions and polymorphic forms, is well known and reviewed (Biliaderis, 1983). DSC applications has also been suggested as a valuable tool for cauterization of oils from vegetable sources (Che Man & Tan, 2002; Tan & Che Man, 2002) and thermal parameters have been reported to correlate well with chemical parameters obtained with standard methods (Tan & Che Man, 2000).

In food industry, DSC has numerous applications for monitoring thermal events discussed earlier such as melting, crystallization, as well as decomposition, denaturation, dehydration, polymorphism, oxidation, etc (Lyubarev & Kurganov, 2000, Boye & Alli, 2000, and Nomura et al., 2000). For example” the effect of storage temperature on phase transitions of the lipid components” in apple and capsicum cuticles was studied using DSC, and it was found that at “low temperatures, the cuticular membrane underwent a

change in structure and the melting enthalpy of the waxes present decreased.” (Lyubarev & Kurganov, 2000).

2.2.4 Fourier Transform Infrared (FTIR) Spectroscopy

Because of the development of Fourier transform infrared (FT-IR) spectroscopic instrumentation, the application of this technique expanded in food research and particularly has become a powerful analytical tool in the study of edible oils and fats. FT-IR spectroscopy is a rapid, non-destructive technique with minimum sample preparation necessary. It allows the qualitative determination of organic compounds as the characteristic vibrational mode of each molecular group which causes the appearance of bands in the infrared spectrum at a specific frequency, which is further influenced by the surrounding functional groups. Infrared spectroscopy is among the most powerful spectroscopic techniques for food analysis since it covers the details on functional group as well as chemical composition that are contained in the infrared spectrum of specific substances (Kumosinski & Farrell, 1993).

Infrared spectroscopy is widely used in both academic research and industry as simple and reliable technique for measurement, quality control and dynamic analysis. It has been highly successful for applications in both organic and inorganic chemistry. Infrared spectroscopy has been utilized for determining a range of adulteration problems in food products such as lard content in cakes and chocolates (Che Manet *et al.*, 2005), lard in mixture of animal fats (Syahariza *et al.*, 2005), adulteration in jam (Defernez & Wilson, 1995), extra virgin olive oil (Lai *et al.*, 1995) and coffee (Paradkar & Irudayaraj, 2002). Currently, Rohman & Che Man (2010) have also used FTIR spectroscopy in combination with partial least square (PLS) and discriminant analysis for quantification of lard in binary mixtures with other animal fats of beef, chicken and mutton. In addition to its application in the detection of edible oil adulteration, FTIR was also used in the studies of thermal stability of edible oils (Moros *et al.*, 2009; and Pinto *et al.*, 2010).

2.3 Chemometrics

In 1972, Svante Wold and Bruce Kowalski in (1976) introduced the notation chemometrics. After that, the foundation of the International Chemometrics Society in

1974 led to the first description of this discipline. The development of the chemometrics discipline is much related to the usage of computers in chemistry. In the 1970s, some analytical groups were already working with statistical and mathematical methods that are described nowadays as chemometric methods (Matthias, 2007).

In the following years, series of conferences were organized; e.g., Computer-Based Analytical Chemistry (COBAC), Computer Application in Analytics (COMPANA), and Chemometrics in Analytical Chemistry (CAC). Later on, novel chemometric journals were started, such as the Journal of Chemometrics (Wiley) and Chemometrics and Intelligent Laboratory Systems (Elsevier).

Frank and Kowalski in (1984) have defined chemometrics as the chemical discipline that uses mathematical and statistical methods, (1) to design or select optimal measurement procedures and experiments, and (2) to provide maximum chemical information by analyzing chemical data.

Chemometric methods applications usually are to develop the quantitative structure activity relationships or to evaluate the analytical–chemical data (Matthias, 2007). The generation of the flooding data by modern analytical instrumentation is one reason; especially analytical chemists develop chemometric applications techniques (Desire, 2003). In addition, in analytics chemometric methods are the discipline that uses statistical methods and mathematical to get appropriate information on material systems. Matthias in (2007) added that a new age commenced for gaining, processing and interpretation of chemical data at the beginning of the 1980s because of the availability of personal computers. In fact, today every scientist uses software, in one way or another that is related to mathematical methods or to processing of knowledge. Therefore, the need appears for a deeper understanding of those methods.

Moreover, making complicated mathematical methods possible was one of the novel aims of chemometrics due to unsatisfactory knowledge of the education of chemists in mathematics. On the other hand, many authors have claimed that, sometimes, analytical chemists have used chemometrics methods as a tool to solve problems resulting from the lack of selectivity such as (Booksh et al., 1997; Aboul-Enein, 2000, and Vessman et al.,

2001) in analytical signals, including the chromatographic signals. Since its beginning, chemometrics has played an important role in resolving food chemistry problems. It has been used in very wide applications in food and beverages such as: grading of raw materials (Cadet et al., 1990); routine on-line quality checks (Lindberg et al., 1985, Robert et al., 1987); minimizing sample preparation (Cowe et al., 1987); and determining process by which product was made (Downey et al., 1990). However, the principal component analysis (PCA) as a technique of qualitative analysis of the data and PLS regression analysis as a technique to obtain quantitative prediction of the parameters are the most used as chemometric techniques (Naes et al., 2002; Wold et al., 2001; Nicolai et al., 2007; Cen & He, 2007). Nowadays, food problems represent one of the major areas of chemometrics applications, and food chemical data are often used for the development and estimate of novel chemometric tools and approaches (Forina et al., 2008).

2.3.1 Principal Component Analysis (PCA)

Eui-Cheol Shin in 2010 has defined principal component analysis (PCA) as a multivariate modeling and analysis technique commonly used in chemometric studies. PCA is a technique of expressing the data in such a way as to emphasize their similarities and differences, and identifying patterns in data. It can compress the data, that is, by reducing the number of dimensions without much loss of information based on their similarities and differences, and define a limited number of “principal components” which describe independent variation structures in the data. Kamal-Eldin & Andersson in (1997) added that it is possible to visualize the data by different plotting systems when more than three variables have been analyzed. Therefore, PCA can indicate relationships among groups of variables in a data set and show relationships that might exist between objects.

Moreover, the PCA basis has been well-explained both qualitatively (e.g. Meglen, 1992) and mathematically (e.g. Lattin et al., 2003). In brief, a dataset is re-expressed in a rotated coordinate system in which as much variance as possible is explained by the first few dimensions. PCA is particularly useful in examining correlations among variables in

the original dataset, since it chooses the new axes to lie along directions of highest correlation (Gotelli & Ellison, 2004). The projection of each variable on the new axis is called its loading, which indicates the relative importance of each variable on that axis; the projection of each sample in the new axis is called its score (Meglen, 1992) or site score (Gotelli & Ellison, 2004). PCs are linear combinations of variables, with the first PC as the scores of all the samples on the first axis, and second as the sample scores on the second axis, and so forth (Zou et al., 2004). Therefore, PCA can indicate relationships among groups of variables in a data set and show relationships that might exist between objects.

Because of the capability to manage and interpret large data sets, PCA has been effectively employed to define relationships that exist in fatty acid characterisation studies of food lipids (Kadegowda, Piperova, & Erdman, 2008; Matos et al., 2007). PCA has been used to establish the authenticity and adulteration of olive oils from different origins. for instance, (Matos et al., 2007 and Lisa et al., 2009) have used PCA to detect the adulteration of olive oil with eleven vegetable oils, such as soybean, sesame, apricot, peanut and olive oils were investigated. In addition, Gutierrez et al., (2009) and Rohman et al. (2012) were able to detect the adulteration in milk fats and animal triacylglycerols by chromatographic system using PCA techniques. Furthermore, Hashim, et al., 2010 successfully differentiated between bovine and porcine gelatins using FTIR coupled with PCA techniques.

2.3.2 K-mean Cluster Analysis

Clustering is a process of grouping data into classes so that objects within a class have high similarity in comparison to one another, but are very dissimilar with respect to objects in other clusters. The goal of a cluster analysis is to find an optimal grouping for which the observations or objects within each cluster are similar, but are dissimilar to the objects in other clusters.

Cluster analysis has been widely applied to data in many disciplines, such as market research, biology, medicine, economics and engineering. The K-means method of

cluster analysis is popular due to its simplicity. In this method, clusters are formed by specifying the number of clusters, say k , and assigning each object to one of the K -clusters in order to minimize the sum of distances from the mean of each cluster. In general, the number of clusters in the data is not known in advance (Bacher, 2002). According to (Che Man et al., 2011) cluster analysis (CA) has an advantage over PCA where CA information is more objective and provides numerical results. In addition, CA is able to reduce dimensionality, while retaining the required information.

