Medium Chain Triglycerides: A Brief Review

Radzuan J* , Nor Aini I * and M S A Yusoff *

ABSTRAK

MCTs adalah minyak yang kandungannya terdiri daripada asid kaprilik dan asid kaprik dengan sedikit kandungan asid kaproik dan laurik. Walaupun MCTs adalah minyak, ia lebih bersifat seperti karbohidrat dengan sumber tenaga sebagai kalori sebanyak 8.3kcal/g. MCTs bersifat cecair walaupun mengandungi sepenuhnya rantai tepu asid lemak. Ini menyebabkan ia sangat stabil kepada oksidasi. Lelemak laurik seperti babassu, kelapa dan minyak isirong sawit adalah sumber utama bagi penyediaan MCTs. Tidak seperti minyak konvensional yang lain, MCTs disalurkan melalui vena portal dan bukan melalui sistem limpa. Ini menjadikan MCTs mudah dihadam, diserap dan disalurkan. MCTs dengan pantas dioksidasikan dan kurang cenderung untuk disimpan sebagai lemak badan. Ini menjadikan MCTs sumber tenaga yang banyak dan cepat. Disebabkan oleh sifat istimewa fizikal dan kimianya, MCTs digunakan sebagai sumber tenaga bagi ahli sukan, orang tua dan bayi tidak cukup bulan. MCTs juga sangat berguna bagi mengawal kegemukan dan paras kolesterol.

INTRODUCTION

The history of medium chain triglycerides (MCTs) dates back to 1955 when they became commercially available. Hospitals began to use them in enteral formulations for patients with malabsorption syndromes (Greenberger and Skillman, 1969; Freedman and Nylund, 1980). MCTs consist of 1% - 2% C6, 65% - 75% C8, 25% - 35% C10 and 2% C12 fatty acids. Although MCTs are fats, they are different from conventional fats and oils (Babayan, 1968) and sometimes tend to behave more like carbohydrates. The caloric value of fat is 9kcals/g while that of MCTs is 8.3kcal/g (Bach and Babayan, 1990). MCTs are a concentrated source of calories compared to 4kcal/g for carbohydrates and protein. They are also a good source of acetyl groups that are useful in lipid synthesis (Bach and Babayan, 1990). This makes MCTs a preferred food for anyone who requires increased energy, such as under-nourished patients after major surgery or children during normal or retarded growth. Lauric fats such as babassu, coconut and palm kernel oils are the main sources of the fatty acids required for the preparation of MCTs.

PROPERTIES OF MEDIUM CHAIN TRIGLYCERIDES

Physical Properties

MCTs are nearly colourless oils with neutral odour and have a slight coconut flavour. This is due to the purification steps that consist of bleaching, deodorization and ultrafiltration. The acid value is limited to 0.1% as lauric to avoid the unpleasant goat-like odour and taste of free caprylic and capric acids. The hydroxyl value of MCT is limited to five. This is to ensure that all fatty acids are esterified to triglycerides and the bitter taste of medium chain monoglycerides is minimized (Timmermann, 1994).

MCTs are the only edible liquid oils containing exclusively saturated fatty acids and are therefore very stable against oxidation. MCTs have a shelf life of nearly 30 years during storage at low temperature and have resistance to polymerization at high temperatures. Even after heating for 24 hours at 230°C, the viscosity of MCTs is still comparable to that of vegetable oils stored at room temperature.

Another important property of MCTs is their excellent cold stability. For example, pure capric acid triglycerides have a sharp melting point of about 30°C, while pure caprylic acid triglycerides melt at about 15°C. However, triglycerides containing C8 and C10 fatty acids melt at considerably lower temperatures (–15°C). They can be stored at very low temperatures without the tendency to crystallize and without the necessity for warming up. MCTs also have very low viscosity of about 30mPa/s, corresponding approximately to one-third the viscosity of normal

* *Palm Oil Research Institute of Malaysia, P.O. Box 10620, 50720 Kuala Lumpur, Malaysia.*

vegetable oils. The smoke points of MCTs are lower (about 150°C) than those of natural vegetable oils due to their lower moleculer weights. Therefore, the use of MCTs in roasting and frying is almost impossible (Timmermann, 1994)

Unlike conventional triglycerides, MCTs are absorbed through the portal vein and not through the lymphatic system. They are not carnitine dependent for transport, do not require chylomicron formation and are less likely to be stored in adipose tissue. They are readily metabolized for energy, more easily oxidized through the β-oxidation pathway and more likely to undergo elongation and deposition compared to regular triglycerides (Akoh, 1995).

Food products with low pH value, high water content or with ingredients having lipase activity tend to undergo hydrolysis. The hydrolysis that takes place in products containing MCTs yield medium chain free fatty acids and medium chain monoglycerides. A small amount of medium chain fatty acids may give rise to an unpleasant colour and taste. This means medium-chain triglycerides should not be used in acidic foods. Pasteurization or sterilization, however, can eliminate any related lipase activity (Timmermann, 1994).

Absorption of Long Chain and Medium Chain Triglycerides

Absorption of long chain triglyceride begins in the mouth where a lipase is secreted from glands near the tongue. Most of the hydrolysis takes place in the stomach at pH of about 4.5-5.5. In the duodenum, the major portion of the fats are emulsified by bile acids and bile salts. This is followed by hydrolytic separation mainly through the action of pancreatic lipase (Gurr, 1997). This results in the formation of glycerine and free fatty acids as well as mono- and diglycerides. Together with bile salts, the digestion of fats becomes easier because the breakdown product, glycerine, is water-soluble and it can get through the intestinal wall. The fatty acids and the monoglycerides must nevertheless first be packed together in the form of micelles so that they can be transported into the intestinal wall (Brand, 1990).

In the intestinal wall, the fatty acids are re-esterified with glycerine to form triglycerides. With proteins, these triglycerides are repackaged as lipoproteins (Brand, 1990). They are finally transported to the liver, fat depot and tissue. *Figure 1* shows the absorption mechanism of long chain triglycerides (Gotoh, 1997).

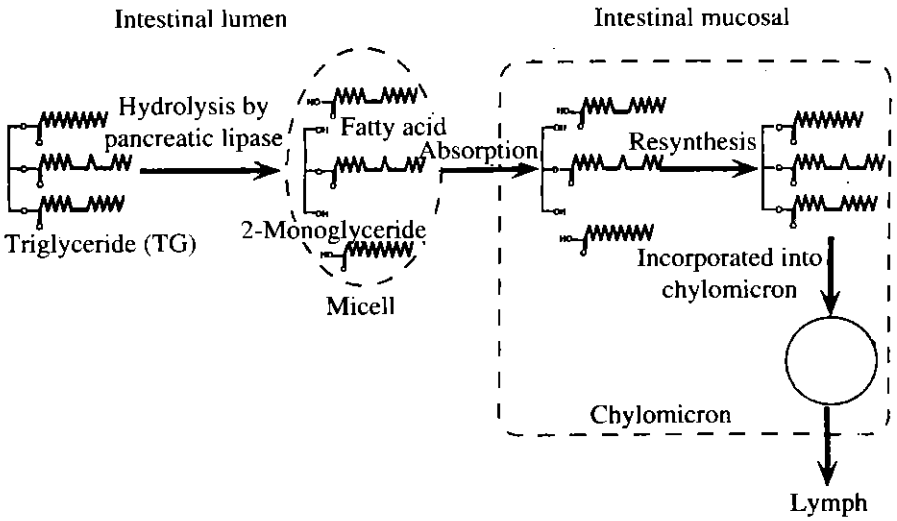
Due to their physical and chemical properties, absorption of medium chain triglycerides differs considerably from that of long chain triglycerides. They have smaller molecular sizes and have better solubility than long chain fatty acids. The broken down medium chain fatty acids and glycerides from MCTs are absorbed faster than long chain triglycerides. They immediately get into the liver through the portal vein without resynthesis and repackaged as lipoprotein. The other pathway for MCTs is that the intact MCTs as triglycerides (not broken down), get to the intestinal mucous without micelle formation, and are transported through the portal vein into the liver as shown in *Figure 2* (Gotoh, 1997; Gurr, 1997).

Clearly, the beneficial effects of MCTs are: i) they are digested, absorbed and transported easily and rapidly; ii) MCTs are oxidized rapidly and have a very low tendency to deposit as body fat; and iii) they are a source of abundant and rapidly available energy.

Production of Medium Chain Triglycerides

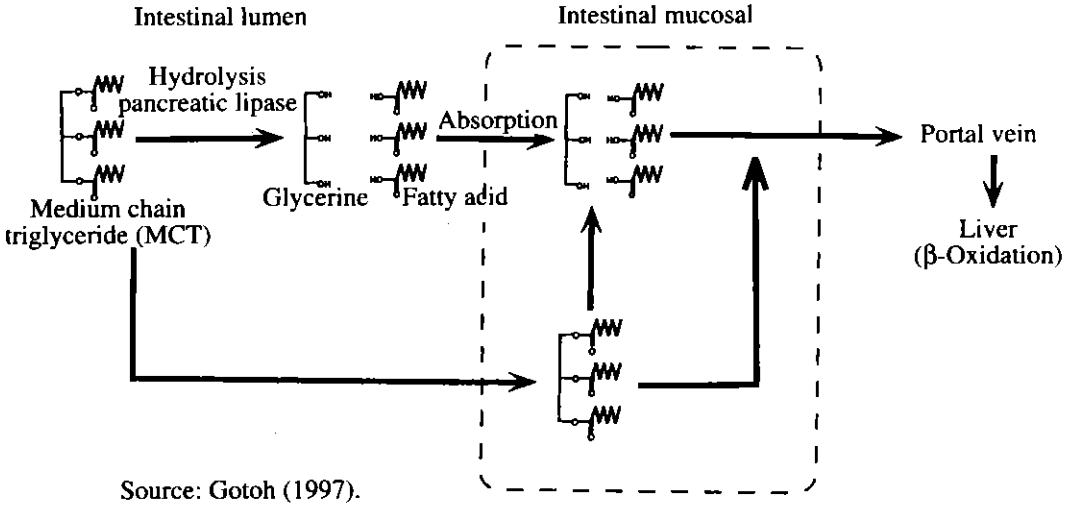
Head-distilled fractions of coconut and palm kernel fatty acids are used as starting materials in the preparation of MCTs. They are esterified with glycerine in the presence of metallic or slightly acidic catalyst. The crude ester is then refined, bleached and deodorized. It is essential that complete esterification takes place to ensure that the final product has a bland flavour. Under normal esterification conditions, the resulting MCTs will be randomly distributed. The ratio of the esters present can be predicted from the ratio of the fatty acids used in the feed (Babayan, 1968). *Table 1* shows a typical MCT oil specification.

Methods for the preparation of MCTs have been documented in a number of patents. A patent by Franzke was the most informative (Hartman



Source: Gotoh (1997).

Figure 1. Absorption mechanism of triacylglycerol.



Source: Gotoh (1997).

Figure 2. Absorption mechanism of medium chain triacylglycerol.

TABLE 1. TYPICAL MCT OIL SPECIFICATIONS

Free fatty acids (as oleic)	0.1% (% as lauric acid)
Saponification value	345 - 355 mg KOH/g
Iodine value	1.0 I_2/100g
Colour (Lovibond)	1.0R 10 Y
Unsaponifiable matter	0.5 (% by weight)
Hydroxyl value	5.0% mg KOH/g

Source: Babayan (1968).

and Reimann, 1989). The patent described the use of caprylic acid (C8:0) in the preparation of MCT that involved esterification. The work was carried out in a nitrogen saturated atmosphere at 145°C-180°C with the aid of various types of catalysts. The acid catalysts used were sulphuric, amidosulphonic, toluene p-sulphonic and phosphorous acids. Other catalysts used were zinc powders, zinc chloride and zinc caprylate, tin chloride and tin sulphate. A 10% excess of the medium chain fatty acid in relation to glycerol was employed in all cases. The best results were obtained with the use of zinc caprylate or phosphorous acid as catalyst at 180°C resulting in a light-coloured end product free of monoglycerides after 10hr of reaction. Esterification using sodium hydroxide at 195°C under vacuum took 24 hours to go to completion. It was therefore less satisfactory compared to the other catalysts.

Industrial synthesis of MCTs is more complicated than the preparation of common edible oils. Esterification of medium chain fatty acids with glycerol must be carried out until monoglycerides are eliminated, otherwise it gives a bitter taste. Free fatty acid content of the end product has to be very low and the deodorization creates problems owing to the hydrolytic action of the steam. The use of excess fatty acids in the esterification step is necessary in order to eliminate the formation of monoglycerides. This results in considerable refining losses, which increases the cost of MCT production (Hartman and Reimann, 1989).

Viernes *et al.* (1990) developed a process for MCT production from coconut oil by using natrium hydroxide as catalyst. This was done by optimizing the reaction parameters, namely mol ratio of reactants, temperature, time and catalyst. They managed to obtain yields of 68% with 99% purity (Viernes *et al.*, 1990).

Medium chain triglycerides were also prepared by using lipase. Using commercial lipase from various microbial origins, mono, di and tricaprin were synthesized in isooctane from glycerol and capric acid (Kwon *et al.*, 1996). The results indicated that lipase from *Chromobacterium viscorsum* and *Rhizopus mucor miehei* showed good activity for the production of tricaprin. It was reported that rapid production of monocaprin and dicaprin occurred in the first two hours and decreased as the reaction progressed. Maximum amount of tricaprin was produced after the reaction proceeded for 18 hours.

USES OF MEDIUM CHAIN TRIGLYCERIDES

Many applications of MCTs have been developed because of their unique physical and chemical characteristics. The absorption, transport and metabolism of MCTs are different from conventional fats and oils. MCTs have become an established tool for the treatment of a variety of malabsorption conditions including chyhemia and steatorrhea.

The demand for sports performance products designed for specific activities will increase the use of MCTs as a concentrated source of rapid energy. Although MCTs have not been shown to enhance performance parameters such as speed, their daily consumption is nevertheless believed by some to increase endurance (Merolli, 1997).

Studies have been conducted on MCTs as a source of energy in premature infants. It was concluded that a preterm infant absorbed MCTs better than long chain triglycerides and this fact has been extensively used in specially adapted preterm infant formulas (Putet *et al.*, 1987). In these studies, total fat oxidation was lower than that of MCTs. MCTs content of preterm infant formula has been recommended not to exceed 50% of total fat colories.

MCTs do not appear to contribute to the blood lipid levels including total blood cholesterol. They are also not deposited in the adipose

TABLE 2. CHARACTERISTICS OF MCTs THAT JUSTIFY THEIR USE IN FOOD PRODUCTS

Unique in composition and in metabolic characteristics.
Possess GRAS (generally recognized as safe) status.
Better and more rapid energy source than proteins and carbohydrates.
Carnitine independent.
Useful in the control of obesity.
Lower cholesterol in serum and tissues.
Non-tumour promoting fat.
Useful in treating malabsorption cases.
Useful in treating childhood epilepsy.
Useful in treating cystic fibrosis.
Represent a protein sparing fat.

Source: Babayan (1991).

tissue in any significant quantity (Babayan, 1974). For new-born infants, MCTs not only assist in their initial growth, but also contribute to their physiological well being (Babayan, 1981). In studies which may have some bearing on ageing and arteriosclerosis, it was found that rats fed with MCTs reduced depot fat accumulation as well as serum and tissue cholesterol (Kaunitz, 1990). MCTs were also prepared as food and given to patients who needed energy beyond that available from glucose and protein. Based on previous findings, it will be a good move to introduce a line of MCTs based food products as justified in *Table 2* (Babayan, 1991).

A ketogenic diet consisting of 60% MCT oil, 20% protein, 10% carbohydrate and 10% other dietary fats was provided to a select group of paediatric patients with advanced stage cancer to test the effects of dietary induced ketosis on tumour glucose metabolism. The introduction of MCT oil based ketogenic diet in a paediatric population with advanced stage cancer was considered to be successful as reported by Nebeling (1995).

Other than cancer, studies on the nitrogen losses and decreased fat in patients with AIDS receiving medium chain triglyceride enriched formulas and formulas containing long chain triglycerides were carried out. The studies showed that although impaired fat absorption occurred in subjects fed both the MCT and control liquid formula, the MCT containing formula appeared to be better tolerated by patients with fat malabsorption and AIDS (Craig *et al.*, 1997).

CONCLUSION

Malaysia, being the largest producer of palm kernel oil in the world has the potential to produce MCTs. The main components of MCTs are caprylic and capric acids. The sources of these fatty acids are palm kernel oil and coconut oil. With the expansion of oil palm cultivation in Malaysia, the availability of palm kernel oil will also increase and it would be economically feasible for Malaysia to produce and export MCTs. The many uses of MCTs are also a virtue and their uses are expanding everyday. It is truly the right time for the Malaysian palm oil industry to produce MCTs for world consumption.

ACKNOWLEDGEMENT

The authors would like to thank the Director-General of PORIM for permission to publish this paper.

REFERENCES

AKOH, C C (1995). Fats replacers present and future. *Latin American Congress and Exhibit on Fats and Oils*. 25-28 September 1995. p. 83 – 94.

BABAYAN, V K (1968). Medium chain

triglycerides – their composition, preparation and application. *J. Amer. Oil Chem. Soc., 45(10)*:23-25.

BABAYAN, V K (1974). Modification of food to control fat intake. *J. Amer. Oil Chem. Soc., 51(6)*: 260-264.

BABAYAN, V K (1981). Medium chain length fatty acid esters and their medical and nutritional applications. *J. Amer. Oil Chem. Soc., 58(10)*: 49A-50A.

BABAYAN, V K (1991). Medium chain triglycerides for food use. *Lipid Technology, 3(3)*: 92-94.

BACH, A C and BABAYAN, V K (1990). Medium chain triglycerides: an update. *Coconuts Today Special Issue for XIth World Congress of Cardiology*, Manila, February 11-16, p. 38 – 51.

BRAND, G (1990). Medium chain triglycerides. *Coconuts Today Special Issue for XIth World Congress of Cardiology*, Manila, February 11-16, p. 32-37.

CRAIG, C B; DARNELL, B E; WEINSIER, R L; SAAG, M S; MULLINS, L; LAPIDUS, W L; ENNIS, D M; AKRABAWI, S S; CORNWELL, P E and SAUBERLICH, H E (1997). Decreased fat and nitrogen losses in patients with AIDS receiving medium chain triglycerides encriched formula, *vs.* those receiving long chain triglycerides containing formula. *Journal of the American Dietetic Association, 97(6)*: 605 – 611.

FREEDMAN, H I and NYLUND, B (1980). International fat digestion, absorption and transport. *Ame. J. of Clinical Nutrition, 33* : 1108-1139.

GREENBERGER, N J and SKILLMAN, T G (1969). Medium chain triglycerides. *N. Engl. J. Med., 230* : 1045-1058.

GOTOH, N (1997). Fat replacer. *J. Japan Oil Chem. Soc., 46 (10)* : 237-245.

GURR, M (1997). Fat digestion and assimilation. *Lipid Technology, 9(4)* : 94 – 99.

HARTMAN, L and REIMANN, D (1989). Preparation of medium chain triglycerides with the use of physical refining. *Fat. Sci. Technol, 91(8)*: 324 – 327.

KAUNITZ, H (1990). Biological and therapeutic effects of MCT (medium chain triglycerides) from coconut oil. *Coconut Today Special Issue for XIth World Congress of Cardiology*. Manila, February p. 55 – 58.

KWON, D Y; SONG, H N and YOON, S H (1996). Synthesis of medium chain glycerides by lipases in organic solvent. *J. Amer. Oil Chem. Soc., 73(11)*: 1521 – 1525.

MERROLLI, A (1997). Medium chain lipids: new sources, uses. *Inform, 8(6)*: 587 – 603.

NEBELING, L C (1995). Implementing a ketogenic diet based on medium chain triglycerides oil in pediatric patients with cancer. *Journal of the American Dietetic Association, 95(6)*: 693 – 697.

PUTET, G; THELIN, A; PHILIPPOSSIAN, G; LIARDON, R; ARNAUD, M J; SENTERRE, J and SALLE, B (1987). Medium chain triglycerides as a source of energy in premature infants. *Nestle Nutrition Workshop Series, Vol. 13*: 43 – 49.

TIMMERMANN, F (1994). Production and properties of medium chain triglycerides. *Lipid Technology, 6(3)* : 61-64.

VIERNES, C H; BINLAYO, D L; GONZALES, A L and ARIDA, V P (1990). Development of a process in the manufacture of medium chain triglycerides (MCT) from coconut oil. 1. Optimization of the reaction parameters. *The Philippine Journal of Coconut Research and Development Foundation, XV(2)*: 4 – 9.