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°C

(% /) (% /)

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sn-1, 3

TAG

(Akoh,

.1997)

.(Ozturk *et al.*, 2010)

(TAG)

(Osborn

.&Akoh, 2002)

(-Oxidation β)

.(Odle, 1997)

TAG

.(Iwasaki & Yamane, 2000)

1 . Medium Chain Fatty Acids
2 . Medium Chain Triacylglycerol

(Ko *et al.*, 2003)

(Nunes *et al.*, 2011)

Iwasaki *et al.* (Kennedy, 1991)

(%) DHA (1999)
(%) DPA

(Zhao *et al.*, 2007)

DPA DHA *sn*-1, 3
% *sn*-2

(C₈) (C₁₀)

Jennings & Akoh (1999)

MLM

%
Senannayake, & (2002) Shahidi

()
()

% /
Hamam & (2005) Shahidi

(Lipozyme TL IM)

DPA DHA

Thermomyces)

(*Lanuginosa*)

()

(% /)

(Novo Nordisk A, S Bagsvaerd, Denmark)

(2007) Zaho *et al.*

%

C_{10:0} C_{8:0}

%

C_{20:0} C_{18:3} C_{18:2} C_{18:1} C_{18:0} C_{16:0} C_{13:0}

°C

% /

(Sodium Cholate)

(Pancreatic Lipase)

sn-2

(Medium-Long-Medium Fatty Acids) MLM

(Xu *et al.*, 1998)

- 1 . Chylomicrons
- 2 . Adipose Tissue
- 3 . Docosahexaenoic Acid
- 4 . Docosapentaenoic Acid
- 5 . SealBlubber Oil

() (%)

(% /)

) pH= /

(g/L)

(g/L)

pH

(Cruz-Ortiz *et al.*, 2011)

()

(IS-RSDA)

Hamam & Shahidi

(2005)

(/ mm × cm) TLC
() %

pH

pH

cm TLC

()

() %

(2008) Farmani *et al.*

UV ()

R_f= /

1. Wattman

-

sn-2

GC

sn-1, 3

:(Fomuso&Akoh, 2002)

$$sn-1, 3 = [3.(sn-1, 2, 3) - (sn-2)]/2$$

(

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sn-2

.(AOCS, Ch 3-91)

sn-1, 2, 3

()

(2006) Huang *et al.*

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sn-1, 3

.(

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(/)

) Minitab

(14.1

(Vortex)

MSTATC

()

/)
GC

(

(14 A) GC

Restec RT-2560)

FID (

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°C

°C

°C

°C

°C

°C)

(% :

(% /)

(% /)

°C)

(% :

(% /)

(% /)

(IV)

AOCS Cd 1c-85

$$IV=(0.95\times C16:1)+(0.86\times C18:1)+(1.732\times C18:2)(+2.616\times C18:3)+(0.785\times C20:1)+(0.723\times C22:1)$$

1 . Flame Ionization Detector

(Xu *et al.*, 1998)

sn-1, 3

(2007) Zhao *et al.* (°C) (%)

() (°C)

°C
%

(C_{18:0}) (C_{16:0})

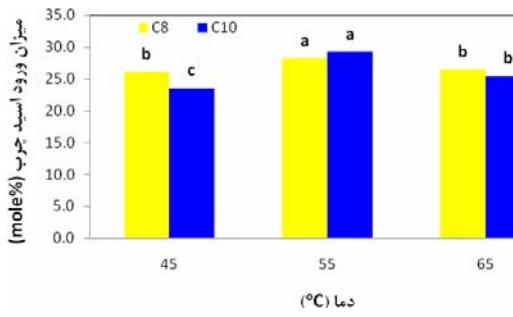
(C_{18:3}) (C_{18:2})

	C _{8:0}	C _{16:0}	C _{18:0}	C _{18:1}	C _{18:2}	C _{18:3}	SFA	USFA	IV
	/ ± / h	/ ± / a	/ ± / a	/ ± / a	/ ± / a	/ ± / a	/ g	/ a	/ ± / a
	/ ± / g	/ ± / b	/ ± / b	/ ± / b	/ ± / b	/ ± / b	/ f	/ b	/ ± / b
	/ ± / f	/ ± / bc	/ ± / b	/ ± / c	/ ± / cd	/ ± / c	/ e	/ c	/ ± / c
	/ ± / d	/ ± / b	/ ± / b	/ ± / d	/ ± / ef	/ ± / cd	/ d	/ d	/ ± / c
	/ ± / e	/ ± / de	/ ± / c	/ ± / f	/ ± / f	/ ± / de	/ b	/ f	/ ± / de
	/ ± / d	/ ± / b	/ ± / b	/ ± / e	/ ± / bc	/ ± / e	/ c	/ e	/ ± / cd
	/ ± / c	/ ± / de	/ ± / c	/ ± / f	/ ± / de	/ ± / e	/ b	/ f	/ ± / f
	/ ± / bc	/ ± / cd	/ ± / c	/ ± / g	/ ± / g	/ ± / e	/ a	/ g	/ ± / ef
	/ ± / ab	/ ± / de	/ ± / d	/ ± / gh	/ ± / g	/ ± / e	/ a	/ g	/ ± / f
	/ ± / ab	/ ± / e	/ ± / c	/ ± / h	/ ± / g	/ ± / e	/ a	/ g	/ ± / f

IV USFA SFA : P<0.05 ±

	C _{10:0}	C _{16:0}	C _{18:0}	C _{18:1}	C _{18:2}	C _{18:3}	SFA	USFA	IV
	/ ± / f	/ ± / a	/ ± / a	/ ± / a	/ ± / a	/ ± / a	/ g	/ a	/ ± / a
	/ ± / e	/ ± / ab	/ ± / b	/ ± / b	/ ± / a	/ ± / b	/ f	/ b	/ ± / b
	/ ± / e	/ ± / c	/ ± / b	/ ± / c	/ ± / cd	/ ± / c	/ e	/ c	/ ± / c
	/ ± / c	/ ± / bc	/ ± / a	/ ± / c	/ ± / b	/ ± / d	/ e	/ c	/ ± / c
	/ ± / d	/ ± / d	/ ± / c	/ ± / e	/ ± / d	/ ± / d	/ c	/ e	/ ± / d
	/ ± / d	/ ± / c	/ ± / b	/ ± / d	/ ± / bc	/ ± / cd	/ d	/ d	/ ± / c
	/ ± / c	/ ± / d	/ ± / b	/ ± / e	/ ± / d	/ ± / cd	/ c	/ e	/ ± / d
	/ ± / b	/ ± / d	/ ± / d	/ ± / f	/ ± / e	/ ± / e	/ b	/ f	/ ± / e
	/ ± / b	/ ± / d	/ ± / d	/ ± / f	/ ± / e	/ ± / e	/ b	/ f	/ ± / e
	/ ± / a	/ ± / d	/ ± / d	/ ± / g	/ ± / e	/ ± / e	/ a	/ g	/ ± / e

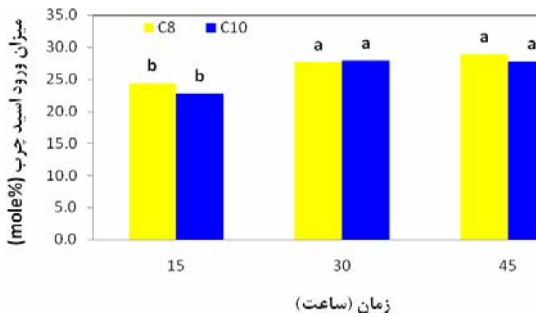
IV USFA SFA : P<0.05 ±



(C₈)

(C₁₀)

(P>0.05)



(C₈)

(C₁₀)

(P>0.05)

()

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()

(Yang et al., 2003)

(Mu et al., 1998)

(2005) Hamam & Shahidi

:

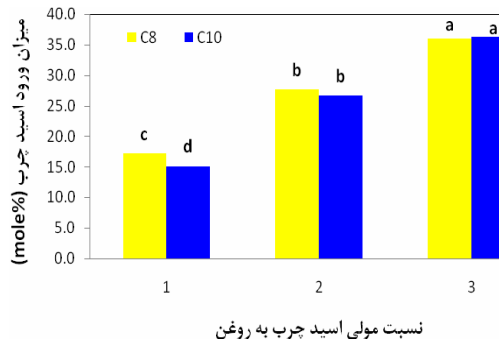
()

(/ ± /)

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Minitab

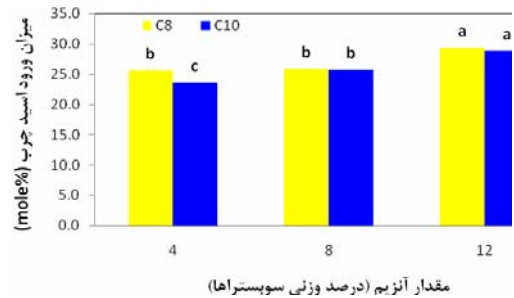
() () ()



(C₁₀)

(C₈)

(P>0.05)



(C₈)

(C₁₀)

(P>0.05)

... :
/ / Senanayake & .
(2002) Shahidi
%
:
% (2007) Zhao *et al.*
%
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(Xu, 2000)
:
(Kuo&Parkin, 1993)
:
(2007) Zhao *et al.* (Zhao *et al.*, 2007)
%
:
(2004) Hamam & Shahidi .
%
% / (2005) Tsuzuki
(2002) Senanayake & Shahidi . %
Jennings . (1999) & Akoh (2003) Paez *et al.*
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(1996) Shimada *et al.*
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% %
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/ / /

(Martinek, 1993)

(Kim et al., 2001)

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(Zhao et al., 2007)

(Hamam &

Zhao et al.

(2007)

.Shahidi, 2005)

°C

(Zhao et al., 2007)

°C

%

(2005) Hamam & Shahidi .

(2007) Zhao et al.

()

sn- sn-2

%

1, 3

sn-1, 3

(Kim

sn-

et al., 2001)

sn-1, 3 2

/ /

.. sn-1, 3

/ / sn-2

TAG	sn-2(mole%)		sn-1,3(mole%)	
	$l \pm l$	$l \pm l (l^a)$	$l \pm l (l^b)$	$l \pm l (l^c)$
C _{10:0}	$l \pm l$	$l \pm l (l^a)$	$l \pm l (l^b)$	$l \pm l (l^c)$
C _{16:0}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:0}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:1}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:2}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:3}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
SFA	l	$l (l)$	$l (l)$	$l (l)$
USFA	l	$l (l)$	$l (l)$	$l (l)$
(sn-2	/TAG		×) × .a	
	(a) .b			
USFA	SFA	TAG .		

sn-1,

3

sn-1, 3

sn-1, 3

sn-1, 3

(Jenning & Akoh, 2000)

(2000) Jennings & Akoh

sn-1, 3

sn-1, 3

(Haumann, 1997)

TAG	sn-2 (mole%)		sn-1,3 (mole%)	
	$l \pm l$	$l \pm l (l^a)$	$l \pm l (l^b)$	$l \pm l (l^c)$
C _{16:0}	$l \pm l$	$l \pm l (l^a)$	$l \pm l (l^b)$	$l \pm l (l^c)$
C _{18:0}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:1}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:2}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:3}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
SFA	l	$l (l)$	$l (l)$	$l (l)$
USFA	l	$l (l)$	$l (l)$	$l (l)$
(sn-2	/TAG		×) × .a	
	(a) .b			
USFA	SFA	TAG .		

() ()

(Zhao et

al., 2007)

sn-1, 3

TAG	sn-2(mole%)		sn-1,3(mole%)	
	$l \pm l$	$l \pm l (l^a)$	$l \pm l (l^b)$	$l \pm l (l^c)$
C _{8:0}	$l \pm l$	$l \pm l (l^a)$	$l \pm l (l^b)$	$l \pm l (l^c)$
C _{16:0}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:0}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:1}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:2}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
C _{18:3}	$l \pm l$	$l \pm l (l)$	$l \pm l (l)$	$l \pm l (l)$
SFA	l	$l (l)$	$l (l)$	$l (l)$
USFA	l	$l (l)$	$l (l)$	$l (l)$
(sn-2	/TAG		×) × .a	
	(a) .b			
USFA	SFA	TAG .		

sn-2 % /

(Yang *et al.*,

.2005)

.(Mu *et al.*, 1998)

.(Xu *et al.*, 1998)

sn-2

sn-1, 3

sn-2

sn-2

MLM

REFERENCES

- Akoh, C. C. (1997). Making new structured fats by chemical reaction and enzymatic modification. *Lipid Technology*, 5, 61–66.
- Anon. (1996). *Official Methods and Recommended Practices of the American Oil Chemists's Society*, 4th ed, 3rd printing. Champaign, IL.
- Cruz-Ortiz, B. R. , Rioz-Gonzalez, A. J. , Garcia, Y. G., Garza, J. A. R. & Rodriguez-Martinez, J. (2011). Immobilization of *Thermomyceslanuginosus* Lipase in PVA-alginate Beads. *Journal of the Mexican Chemical Society*, 55(3), 176-180.
- Farmani, J. ,Hamedi, M. & Safari, M. (2008). Production of zero *trans*Iranianvanaspati using chemical transesterification and blending techniques from palm olein, rapeseed and sunflower oil. *International Journal of Food Science and Technology*, 43, 393-399.
- Fomuso, L. B. & Akoh, C. C. (2002). Lipase-catalyzed acidolysis of olive oil and caprylic acid in a bench-scale packed bed bioreactor. *Food Research International*, 35, 15-21.
- Hamam, F. &Shahidi, F. (2005).Enzymatic incorporation of capric acid into a single cell oil rich in docosahexaenoic acid and docosapentaenoic acid and oxidative stability of the resultant structured lipid. *Food Chemistry*, 91, 583–591.
- Hamam, F. ,&Shahidi, F. (2004). Lipase acidolysis of algal oils with a medium chain fatty acids, capric acid: Optimization using response surface methodology. *Journal of Food Lipids*, 11, 147–163.
- Haumann, B. F. (1997). Structured lipids allow fat tailoring. *International News on Fats, Oils and Related Materials*, 8, 1004-1011.
- Huang, Z. ,Wang, B. & Crenshaw, A. A. (2006). A simple method for the analysis of trans fatty acid with GC–MS and ATe-Silar-90 capillary column. *Food Chemistry*, 98, 593-598.
- Iwasaki ,Y. & Yamane, T. (2000). Enzymatic synthesis of structured lipids. *Journal of Molecular Catalysis B: Enzymatic*, 10, 129-140.
- Iwasaki, Y. ,Han, J. J. , Narita, M. , Rosu, R. , & Yamane, T. (1999). Enzymatic synthesis of structured lipids from single cell oil of high docosahexaenoic acid content. *Journal of American Oil Chemists Society*, 76, 563–569.
- Jennings, B. H. &Akoh, C. C. (1999).Enzymatic modification of triacylglycerols of high eicosapentaenoic and docosahexaenoic acids content to produce structured lipids. *Journal of American Oil Chemists Society*, 76, 1133–1137.
- Jennings, B. H. &. Akoh, C. C. (2000). Lipase catalyzed modification of rice bran oil to incorporate capric Acid. *Journal of Agricultural*

and Food Chemistry, 48, 4439-4443.

- Kennedy, J. P. (1991). Structured lipids: fats of the future. *Food Technology*, 44, 76-83.
- Kim, I. H., Yoon, C. S., Cho, S. H., Lee, K. W., Chung, S. H. & Tae, B. S. (2001). Lipase-Catalyzed Incorporation of Conjugated Linoleic Acid into Tricaprylin. *Journal of American Oil Chemists Society*, 78(5), 547-551.
- Ko, S. N., Kim, H., Lee, K. T., Ha, T. Y., Chung, S. H. & Lee, S. M. (2003). Optimization of enzymatic synthesis of structured lipid with perilla oil and medium chain fatty acid. *Food Science and Biotechnology*, 12(3), 253-256.
- Kuo, S. J. & Parkin, K. L. (1993). Substrate preference for lipase-mediated acyl-exchange reactions with butter oil are concentration-dependent. *Journal of American Oil Chemists Society*, 70(4), 393-399.
- Martinek, K. (1993). Need for thermostability, its benefits and main strategies for thermostabilization. In M. N. Gupta (Ed.), *Thermostability of enzymes* pp. 76-82. Springer-Verlag, Berlin.
- Mu, H., Xu, X., Høy, C. E. (1998). Production of specific-structured triacylglycerols by lipase-catalyzed interesterification in a laboratory-scale continuous reactor. *Journal of American Oil Chemists Society*, 75, 1187-1193.
- Nunes, P. A., Pires-Cabral, P., Ferreira-Dias, S. (2011). Production of olive oil enriched with medium chain fatty acids catalysed by commercial immobilised lipases. *Food Chemistry*, 127, 993-998.
- Odle, J. (1997). New insights into the utilization of medium-chain triglycerides by neonate: observations from a piglet model. *Journal of Nutrition*, 127, 1061-1067.
- Osborn, H. T., Akoh, C. C. (2002). Structured Lipids—Novel Fats with Medical, Nutraceutical, and Food Applications. *Comprehensive Reviews in Food Science and Food Safety*, Vol. 1.
- Ozturk, T., Ustun, G., Aksoy, H. A. (2010). Production of medium-chain triacylglycerols from corn oil: Optimization by response surface methodology. *Bioresource Technology*, 101, 7456-7461.
- Paez, B. C., Medina, A. R., Rubio, F. C., Cerdan, L. E. & Grima, E. M. (2003). Kinetics of lipase-catalyzed Interesterification of triolein and caprylic acid to produce structured lipids. *Journal of Chemical Technology and Biotechnology*, 78, 461-470.
- Senanayake, S. P. J. N. & Shahidi, F. (2002). Enzyme-catalyzed synthesis of structured lipids via acidolysis of seal (*Phocagroenlandica*) blubber oil with capric acid. *Food Research International*, 35, 745-752.
- Shimada, Y., Sugihara, A., Nakano, H., Yokota, T., Nagao, T., Komemushi, S., & Tominaga, Y. (1996). Production of structured lipids containing essential fatty acids by immobilized *Rhizopusdelemar* lipase. *Journal of American Oil Chemists Society*, 73, 1415-1419.
- Tsuzuki, W. (2005). Acidolysis between triolein and short-chain fatty acids by lipase in organic solvents. *Bioscience, Biotechnology, and Biochemistry*, 69, 1256-1261.
- Xu, X., Skands, A. R. H., AlderNissen, J. & Hoy, C. (1998). Production of specific structured lipids by enzymatic interesterification: optimization of the reaction by response surface design. *Fett/Lipid*, 100(10), 463-471.
- Xu, X. (2000). Production of specific-structured triacylglycerols by lipase-catalyzed reactions: a review. *European Journal of Lipid Science and Technology*, 102, 287-303.
- Yang, T., Fruekilde, M. B. & Xu, X. (2005). Suppression of acyl migration in enzymatic production of structured lipids through temperature programming. *Food Chemistry*, 92, 101-107.
- Yang, T., Xu, X., He, C. & Li, L. (2003). Lipase-catalyzed modification of lard to produce human milk fat substitutes. *Food Chemistry*, 80, 473-481.
- Zhao, H., Lu, Z., Bie, X., Lu, F. & Liu, Z. (2007). Lipase catalyzed acidolysis of lard with capric acid in organic solvent. *Journal of Food Engineering*, 78, 41-46.