0 Ð L786àG¬ $ 1 / 0 $ 5 (â LG®@ > F "ïG® ¾G® Ð"ïG®+N"ï ?G¥

í Ü [1] ¸ ‹ ì p [1] ¸ å ŠUÏ [1] ¸Tú F [2] ¸ „ 6 & [2] ¸9 0K, [1] ¸1\ ([3] ¸ g#3 Ë [1] ¸ N Ò [1] ¸ / î [1]
' Ê œ Ö 0 ª 6 0] œ J ˜ _ Ÿ ª 6 c ÿ ^ 7 $ ¬ r É œ J œ < œ J R š \ " ^ ³
• « d œ J œ < œ J % % — 8 % ª 6 « d œ J / V

Ž?· Æ1- 6 -2- • 6 -3- P 6 % 8 a OPL ¾ $ / V ') ¦ N é ˜ º ª 6 { $ $ Ð Ë r p N t í ø … G $ » ANL-MARE Â $ % • OPL º ¥ d Ë r N _ % • ä ¶ ø t … G $ ANL-MARE É » ANL-MARE " ^ Â $ " Ù K t ¢ 5 8 • 6 % 8 a PPPc 6 OA ä P 6 LA : Ò Â $ % • Ã OPL r º ¥ d < æ Ù - ä ¹ ë K Ë r $ f OPL « æ N] ¼ ! PPP 0 ™ » 6 i š ' 1:14.27 OA 0 LA i š ' 1:0.76 » ¦ h 12.70% ± ë 1 g 50 § ± ë 4 h ® ¨ Ñ • ! ^ / OPL - s Ã h 47.93% 2 * • 6 sn-2 PA ½ ™ • 6 PA) h Ó ô sn-2 PA - s Ã h 71.69%d® ó … G $ ANL-MARE 0 e œ » - ' ¶ £ { Ú Â $ æ N OPL c ÿ d ˜ h N í … G $ ANL-MARE n Â $ % • OPL r 7 Ö Ž O $ ™ Ý : Ò % • " b t í Û ä 8 â n „ d

©KdB Æ 6 -2- • 6 -3- P 6 % 8 a " ¼ 6 ¥ "… G $ » " ANL-MARE "] ¼ $
½1 5L - Æ1673-9078(2024)02-109-119 DOI: 10.13982/j.mfst.1673-9078.2024.2.0196

Synthesis of 1-Oleic Acid-2-Palmitic Acid-3-Linoleic Acid Triglyceride via Enzymatic Acidolysis by Immobilized Lipase ANL-MARE

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Abstract: 7KH GHPDQG IRU LQIDQW IRUPXOD VLPLODU WR EUHDVW PLON LV JURZL catalytic preparation of 1-oleic acid-2-palmitic acid-3-linoleic acid triglyceride (OPL), the main lipid component in human PLON XVLQJ D QHZ LPPRELOL]HG OLSDVH $1/ 0$5(7KH LPPRELOL]HG OLSDVH

E · l ? Ö

ç Ö , … æ j, ß „UÉ,1y. * Ê F726ÚG¦ANL-MARE Ü FG¨@ 8 @1-"éG¨-2- ¸G¨-3- Ê"éG¨+H"é 9GŸ [J] .)à O ñ 0 °,2024,40(2):109-119.

KANG Meng, HE Jiaqiang, FENG Konglong, et al. Synthesis of 1-oleic acid-2-palmitic acid-3-linoleic acid triglyceride via enzymatic acidolysis by immobilized lipase ANL-MARE [J]. Modern Food Science and Technology, 2024, 40(2): 109-119.

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0H N¯-$ Ö µ R-70 ¶ »H &ï ÔPÂ ÚN¯-$ - µ R-7 Õ73O ÷#q](ŸH &ï ÔPÂ Ú Ä2018B030322010Å µ 8H &ï.J A× HN¯-$ ÄSL2022B03J01001Å c § 80 ¶ vN¯-$ - µ EG§"ïO © Ý I D °73 IFV.J0¬ Q æ LUN¯-$ ÄCXTD2020006 Å
'6;1¶ Ö í Ü Ä1998Å © È.‹ ! È.J0¬ ï G ÖO ÷ Ö D ¿ ž ÈE-mail Ökangm1189@163.com
FPAå '6; Ö / î Ä1966Å +m È • ! È • ¾ È.J0¬ ï G ÖO ÷ L œ Ã _'l Ý(Ÿ L œ ÈE-mail Öcaoyong2181@scau.edu.cn

FKDUDFWHUL]HG 1H[W DQ HI¿FLHQW HQ]\PH FDWDO\]HG SUHSDUDWLRQ RI OLSL
DQG OLQROHLF DFLG ZDV HVWDEOLVKHG XVLQJ $1/ 0$5(DV WKH ELRFDWDO\VW
VXUIDFH H[SHULPHQWV WKH RSWLPDO 23/ V\QWKHVLV SURFHVV ZDV REWDLQHG
fatty acids molar ratio of 1:14.27; an oleic acid:linoleic acid molar ratio of 1:0.76; the addition of 12.70% ANL-MARE; a
reaction temperature of 50 , and a reaction time of 4 h. Under these conditions, the relative OPL content reached 47.93%, and sn-2
SDOPLWLF DFLG DFFRXQWHG IRU RI WKH WRWDO SDOPLWLF DFLG FRQWHQW UH
WKH LPPRELOL]HG OLSDVH $1/ 0$5(VKRZHG EHWWHU FDWDO\WLF DFWLYLW\ WKDQ
WKH LPPRELOL]HG OLSDVH $1/ 0$5(KDV VLJQL¿FDQW SRWHQWLDO WR FDWDO\]H WKH
SURYLGHV D QRYHO VWUDWHJLFDO DQG WKHRUHWLFDO EDVLV IRU WKH HI¿FLHQW SUH

Key words: 1-oleic acid-2-palmitic acid-3-linoleic acid triglyceride; enzymatic acidolysis; immobilized lipase; ANL-MARE; process optimization

!ý £ _ ¤ o+OK¯ 6â,´*6 #:U «3P Ä £726Ú •!ý £] p [7-Gÿ,´ 45%~55% È ü [J =O¡ ¼72 6ÚG¨ ¼ õM0726ÚG¨ ú Ï7- W72CX È) j ƒ,´ 6â ¼ • ç8# £Gý?± Ä1,3- ¼ =O¡ ¼726ÚG¨-2- ¸G ¨ + H " é 9 G Ÿ 1,3-Di-Unsaturated Fatty Acyl-2-PalmitoylglycerolsÈUPU Å _!ý £72CX,´ k?± ˆ X ' ? È =O¡ ¼726ÚG¨ k?± X+H"éPØ æ,´0û ƒ Ê A } 5ž Ä 6 W H U H R V S H F L ¿ F 1 X P E H U 1 L Q J E S 1 Å OPL ,´ f 7 G¦ óG¨@ # j k È k?± ¸GŸ F È6<O¡ ¼726ÚG¨ ¸G Palmitic Acid ÈPA Å Ä4 Ö60%~70% ÅGŸ F sn-2 } È F /ý5 ´,´+H "é 9GŸ Triacylglycerol ÈTAG Å Î j ¤ ¬ o)72CX ¼./(™CX,´#¸ F ¼ h f Ã óF PØPì 6â ¼ 6ÐFƒ • ç Ã i ´>p$5 ¼6Í7?,´+H"é 9GŸ ¼6ö *G· "d £ óF 72CX BR ÿ A72CX0 3_ È)óF ¤ ¬ o+OK¯ 6â § 9Gý?± Œ+X Ä¦] È 1-"éG¨-2- ¸G¨-3- Ê"éG¨+H"é 9GŸ 1-Oleoyl-2-Palmitoyl-3-LinoleoylglycerolÈOPL Å ¼1,3- ¼"éG¨-2- ¸G¨ +H"é 9GŸ 1,3-Dioleoyl-2-PalmitoylglycerolÈOPO Å _!ý £] Y'f ˆ X,´ T/ý k?± UPU5 ´72 È ¦ [Gÿ = < - æ ¼ ` j,´OžO • 6< 2 Ä OPL _ Ê#b!ý £] 0 ˆ ü,´72CX È T ¦ _ X] -!ý £] Ä17.85%~33.02% Ä "! È OPL X ¤ o,´ @K¯] • UGý?± Œ+X Ä f6< È+a ¾!ý £ ² « =Cã F5j • È ú(‹ £ ¼ =(™"é •$À,´ ¤ oG} é ¦2¹] ~ = [OPL È D¦72CX5 ´ W J jO¡ ¼726ÚG¨ • ž X sn-1,3 } ÈK¯ O t • ¡ ý72CX ¼./(™CX,´ h f Y +X È= Y ¾ ¤ ¬ o+OK¯ 6â È C ,8$ ï0 Ä ! È ê £ / 72 OPL,´ 8 @ § 9Gý?± ? y ÈF) f 7 ¼ 0 0/ý >] - ê £726ÚG¨5 ´ ¼ 6 32« l,´ ê £ 72 / ñ § 9Gý?± Ä+X } Ÿ Ä

F ¤ • È5 ´72CX,´G¦# f 7+a ¾ ¦ ý Ä ' &

$Y ¼ Ã Ü F x)·Q Ã)ß 1y H&é ` ¯# £# È ¦ f 7 é# 6 jGŸ F# ÃG¨@ # ÃEœGŸ F# 1y ÄG¦ óG¨@ # ý Ä$Y ¼ Ã 8ª1° … È Ë ¶ 0/ý 6 pM0 ,´726ÚG¨ 8 ¦ ` TAG ,´(© Ê }5ž 9+X,´ é# È _ 9ç Ç ü [(©!º726ÚG¨,´ TAG 0-$ Õ,´ é ? Ä }È - F 1 J,´ ê £72 / 72 OPO ~ • ž ¶ A - ¤ ¬ o × ñ,´˜G 2 j È6< OPL+O × 8ª ý 4 X.D0¦ ¸ .œ72 >"éG¨ Oleic Acid ÈOA Å Ã Ê"éG¨ Linoleic Acid ÈLA Å F65 ü [OA ¼LA ,´ =(™"é j Ï É X * Ê F726ÚG¦,´ Ü F Œ+X ; 8 @ Wang 1y G +XG¨@ # ¸.œ72 > OA ÃLA Ä ™ D" 1:7:7 Å j Å(™ Ï É È$+ Ð10% NS40086 726ÚG¦ È60 ý Ä 4 h È9ç Ç ×(™] [47.93% OPL Èsn-2 PA( ) [Gÿ j 87.90% Ä – 01y PPP ¼ ü [OA ¼LA ,´ '7&2-"é j Å(™ Ä ™ D" j 1:7 Å È$+ Ð10%,´ Novozym 40086X 55 ý Ä 12 h È9ç Ç OPL-( ) [Gÿ j 42.35% Ä'f6< ÈUPU5 ´72?ô Q F+O × L€ ¾ v J F726ÚG¦ ˆ X,´ ° _ ñ Â ÄF v J726Ú G¦,´Q @ \ ú ü [sn-2 PA"é72 Å(™ •$À,´5j • È L€ f ¶ - µ ê £ / 72,´ × J F È ,8$F OPO ¼OPL × ñ ' l uQ = ; Ä \.D0¦ LO } O.D0¦ * § 9Q Ü F x)· ÃQ 0c Ê W,´ * Ê F726ÚG¦ È / - F v JG¦ f r È " @ Ï Ä+X ¾Q G¨ ' WBv"é ,´7aG¨ ¼ …+H"éGŸ Ã+H"é ¼GŸ,´+O(™ 8 @Ä

\.D0¦OÆ x f 7 ¼>˜ ± * Ê FG¦ ANL-MARE Œ j+O(™ Ü F r È $æ r 6 # üLö Ç `,´ 9 ¸G¨+H"é 9GŸ Tripalmitin ÈPPP Å ú726ÚG¨ ÄOA Ã LA Å Œ j Ï É ÈG¦ óG¨@ # f 7 ü [OPL,´5 ´ 72 È O j óF Q l F ê £72 / 72 OPL,´G¦# f 7 J … ¼ Î)à ~ @ \ × J F Ë*6Aê ò63 Ä

† Ï D ï#

1.1 材料与试剂

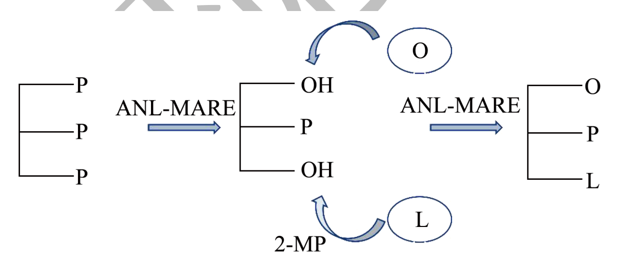
58 ¸.œ72 ÈC]8 ,ú#§ 9Gü ¯ 2Þ"é 9L€ œ (×LA ÃOA w j 6 À4ß ÈC]8 :#§5‡ ™B r œ (× 7 726ÚG¦ ÄUSP4× È § 9 sn-1,3(© 2 W Ã37 /ý72 6ÚG¨+bGŸ$' 8 7 ö ñ È8¢Ba4ß ÈC]8 :#§ Sigma-Aldrich œ (×PPP ÃOPL 7 ö ñ w j8¢Ba4ß ÈC] 8 *Ž ¨ Larodan œ (× * Ê F726ÚG¦ NS40086 Ä • $À ¾$ V S H U J L O O (Ê X U \ ] D H A72 Å ¼ Lipozyme 435 Ä •$À ¾& D Q G L G D $ Q W D U F W L F D I' G¨ A72 ÅC]8 iTÖB*5$ œ (×8¢Ba4× ‰7x Ã 2 IG· Ã+bG· Ã!“ !" È wC]8 !W $ { F – œ (× ;´ r8¢Ba.u7& ¯ Ä 10 cm×20 cm ÅÈC]8 ¯ Ÿ Ç ˜ œ (×726ÚG¦ $ V S H U J L O O X V A Q L U A W H U „ I' G¨ A72 È+a ¯ L-1 Ï7-O ñ#k W(™Gý&é ÎP¼ Ô Ë Ä

1.2 主要仪器与设备

SEDEX 80 »:è y “ 4 ð#{ ˜ Ä Evaporative Light Scattering Detector ELSD ÅÈ# - SEDEX œ (×LC-10A »#â-(8¢Ba ÄLC ÅÈ \ Ë#U ×HP 6890-5973 »"D-(8¢BaCXBa6„+X ÄGC-MS Å DB-WAX " 4ö1Ñ ! È w •8 5¾ - ¹ § V œ (× Dionex Acclaim C30 8¢Ba.u7& ! È5¾ - 7 K H U P R 6 F L H Q W L ¿ F (×R204B3 » ûEœ:è È:#§+c+O0 ° 9L€ œ (× N-EVAP »"^ i È5¾ - organomation œ (Ä

1.3 实验方法

\.D0¦G÷+XG¦ óG¨@ # 8 @OPL È PPP ÃOA ¼LA Œ j ý Ä Å(™ ÈG÷+X sn-1,3 }(© 2 W726ÚG¦ ANL-MARE G¦ óG¨@ # f 7 OPL È8ªD 4ï ² . 1 Ä



* &˘ BF¢ " / - . " 3 & F¢ ïF⁄? " 4 < 0 1 - 7ƒC 3º

Fig.1 Process route for the synthesis of OPL using immobilized enzyme ANL-MARE enzymatic acidolysis

_ ! PPP !8 • 6 % 8 a " 2-MP !2- • 6 æ % a O !6" L !P 6 " OPL !1- 6 -2- • 6 -3- P 6 % 8 a d

§ ƒ ` ÈOÆ x ÈG÷+X$æ r# þ 58 ,´ ¸.œ 72] 6 üLö PPP È Œ j >5 8ª] sn-2 PA,´ Ë ƒ •$À ÄL¿ > È Ð • OA ¼LA X sn-1,3 }(© 2 W ,´ * Ê F726ÚG¦ ANL-MARE Œ+X ; PPP] sn-1,3 }726ÚG¨ È9ç Ç OPL Ä

1.3.1 ANL-MARE » … G $ ƒ ¶ ø

1.3.1.1 726ÚG¦,´ * Ê F

i ž Feng1y[Ø>,´@Ø] È# +• 9 i È F2Gÿ726ÚG¦ ANL 6 “ ¾ 20 mmol/L/'G¨- 5C â$æ#â ÄpH I 5.6 Å] È4 È10 000 J ‘ & ;/ë ó 10 min È : $L#â È f @ 0.50 mg/mL,´726ÚG¦#â Ä0 F2Gÿ4ÿE÷ 5C â- $æ#â#Ö#G,´ W „ I' G¨ A72 È 6 “ ¾726ÚG¦ #â] È ¦ 150 r/min,´FO ÖF 5 5 ü 6 h È ¯726ÚG¦ ¼ A72 u 6 Õ@ Ä 0 > È5C â$æ#â%2#G * Ê F72 6ÚG¦>˜M'!»+‰,´726ÚG¦ È ¦ X45 -O0ª ¢(5 h Ä

1.3.1.2 <û,-CX hLt)·,´#{ Ê

<û,-CX [Gÿ#{ Ê ÖG÷+X ÈCA # #{ Ê<û,-CX [Gÿ Ä * Ê FG¦<û,-CX hLt)·,´AÑ1Ç œ ? ² ; Ö

$$A=\frac{X_1-X_2}{X_1}\times 100\% \quad (1)$$

´ / !

A k k ñ B) k Ñ PL % "

X_1 k k … G $ k • » ¡ / ñ B h mg "

X_2 k k … G $ k … G $ Ò ¡ ƒ • ¡ / ÷ % ñ B h mg d

1.3.1.3 * Ê FG¦G¦#k Ë ð#{

ò'— GB/T 23535-2009 É726ÚG¦ f r ÊF >| È AÑ1ÇG¦,´" #k Ë Ä1°@0 {Š10 mL 9@ +&] Ð • 4 mL CXGÿ 6 4% ,´6Š ‰'G· - t´"é £ F#â Ä V/V Å ¼5 mL 0.025 mol/L/'G¨5C â#â Ä pH I 7.5 Å È'f > Ð • F2Gÿ,´726ÚG¦ È37 ý Ä 15 min > È Ð • 15 mL ƒ0 6 95% ‰G·$æ#â ÄV/V Å4ø!' ý Ä È+X 0.05 mol/L NaOH$æ#â%$ Ê È GŠGŽ j 7/j r È < & Š0ª,-4ô Ä

1.3.1.4 * Ê FG¦,´>˜ ±

i ž Liu 1y[Ø>,´@Ø] È# ÈG÷+X µGü & ’4Ò F y Ba ÄFourier Transform Infrared Spectroscopy, FT-IR Å 6 À ANL-MARE 726ÚG¦ * Ê F } >,´ È7- F È 6 À726ÚG¦ X A72 : * Ê F,´0; Ö Ä

1.3.2 PPP Ó ” ,

G÷+X$æ r 6 # þ 58 ¸.œ72] üLö PPP[Ø>] Ä[@Ø] OÆ x 6 ¸.œ72 u 6$æ@ È 6 IGž 5 mL/g,´" » > ¸.œ72$' 8 È X 38 M‰5ž 4 h È µ PPP À * > EõFO í% ÈL¿ > 6 p Ç.œ72 X0 ûEœ:è 7a ë

$æ r È9ç ÇQ 4ñ PPP ×(™ Ä 6 ×(™ LC-ELSD ð #{ PPP [Gÿ ÈGC-MS ð#{726ÚG¨ Ä

1.3.3 OPL ¼6 æ N

1.3.3.1 OPL,´G¦ óG¨@ … 3PB P¼

i ž } O.D0¦ *.p È H F ¡ ýG¦ óG¨@ ý Ä,´ Z £K^ ¡ ý 3P Ä 6 6 üLö Ç `,´ PPP > OA ¼LA 9 0 Ê ™ D" ÄOA > LA ™ D" j 1:0.5 Ã1:0.75 Ã1:1 Ã1:1.25 Ã1:1.5×PPP > k726ÚG¨,´ Å(™ ™ D" j 1:8 Ã1:10 Ã1:12 Ã1:14 Ã1:16 Å$+ Ð8#' +&] È ¾60 $' 8$æ@ Ä ½ A ƒ3+] Ð • 0 ÊCXGÿ 6 ,´ * Ê FG¦ ANL-MARE Ä Å(™ kCXGÿ,´6% Ã8% Ã10% Ã12% Ã14% ÅÈ X 0 Ê"d#¤$Y Ö ;50 Ã55 Ã60 Ã65 Ã70 Å150 r/min ý Ä 0 Ê &L$ Ä1 Ã2 Ã4 Ã6 Ã8 Ã10 h ÅÄ ý Ä5 • > ÈE÷% L"G¦ È9ç ÇG¦ ó 8 @ ×(™ È 6/ë ×(™] TAG Ä … 3PB P¼ OPL • k TAG ,´ -( ) [Gÿ ¼ sn-2 PA • k PA ,´CXGÿ 6 Ä sn-2 PA È -( ) [Gÿ Å j 7 7 ÈAô ' OPL,´ [Gÿ ¼ ×(™]G * Eœ0+,´)àB' Äý ÄGý =F >| 3!Q Ä§ ƒ ý Ä ò ² ; Ö

Ä1 Å63 OA > LA ™ D") 8 @ OPL,´ ¡ ý Ö PPP >726ÚG¨ Å(™ ™ D" 1:12 È ý Ä$Y Ö j 60 È ý Ä &L$ j 6 h È726ÚG¦ANL-MARE $+ ÐGÿ j Å(™ kCXGÿ,´12% ÈOA > LA ™ D" j 1:0.5 Ã1:0.75 Ã1:1 Ã1:1.25 Ã1:1.5 Ä

Ä2 Å63 Å(™ ™ D") 8 @ OPL,´ ¡ ý Ö OA > LA ™ D" 1:0.75 È726ÚG¦ANL-MARE $+ ÐGÿ j Å(™ kCXGÿ,´12% È ý Ä$Y Ö j 60 È ý Ä &L$ j 6 h ÈPPP >726ÚG¨ Å(™ ™ D" j 1:8 Ã1:10 Ã1:12 Ã1:14 Ã1:16 Ä

Ä3 Å63 726ÚG¦ANL-MARE $+ ÐGÿ) 8 @ OPL,´ ¡ ý Ö Å(™ ™ D" 1:12 ÈOA > LA ™ D" 1:0.75 È ý Ä$Y Ö 60 È ý Ä &L$ 6 h È726ÚG¦ ANL-MARE $+ ÐGÿ j Å(™ kCXGÿ,´6% Ã8% Ã10% Ã12% Ã14% Ä

Ä4 Å63 ý Ä$Y Ö) 8 @ OPL,´ ¡ ý Ö Å(™ ™ D" 1:12 ÈOA > LA ™ D" 1:0.75 È ý Ä &L$ j 6 h È726ÚG¦ANL-MARE $+ ÐGÿ j Å(™ kCXGÿ,´12% È ý Ä$Y Ö j 50 Ã55 Ã60 Ã65 Ã70 Ä

Ä5 Å63 ý Ä &L$) 8 @ OPL,´ ¡ ý Ö Å(™ ™ D" 1:12 ÈOA > LA ™ D" 1:0.75 È ý Ä$Y Ö j 60 È726ÚG¦ ANL-MARE $+ ÐGÿ j Å(™ kCXGÿ,´12% È ý Ä &L$ j 1 Ã2 Ã4 Ã6 Ã8 Ã10 h Ä

1.3.3.2 OPLG¦ óG¨@ 8 @,´ ý ÄM'B P¼ H F

* ¾ … 3PB P¼5 Ì ÈF >| ý ÄM' H F 6 À È F9) OPL -( ) [Gÿ ¼ sn-2 PA-( ) [Gÿ 9 n:‡ ¡ ý,´ 3 Z 3P ÖANL-MARE 726ÚG¦$+ ÐGÿÅÃ PPP >726ÚG¨,´ Å(™ ™ D" ÈÃ OA > LA ™ D " ÄC ÅÈF >| 3 3P 3 "d £,´ ý ÄM' 6 À ÎP¼ È) OPL G¦# 8 @,´ 8ªF >| H F Ä ÎP¼G÷+X Box-BehnkenAîAÑ È] ó ÎP¼!Q j 3 !Q È 4 Z 3P,´ "d £ ²>˜ 1 Ä

= # P Y # F I O L F OA O,@Œ@˝ 2L!'

Table 1 The factors and levels of Box-Behnken test

<	Ù -		
	A/%	B	C
-1	10	1:12	1:0.5
0	12	1:14	1:0.75
1	14	1:16	1:1

1.3.4 ¼6 ! ^ /TAG Ó6

ò'—Q Þ1ÿ ´ ,´ ë# È 6!" !'' >G¦ óG¨@ ×(™ 10 mL/g,´" »$' 8 È ½ Ð •$h/ë726ÚG¨ 1.5 = ™ D ƒ Gÿ,´0.5 mol/L KOH-CH_3CH_2OH $æ#â Ä30% ÈV/V ÅÈ u 6$' 0 ÃM‰5ž 6 r È h : r [9 TAG ,´!" !"-(È45 ûEœ:è f$æ r Ç ` TAG Ä

1.3.5 ! ^TAG Ó e

= - $"C6]/7 »

Table 2 LC elution procedure

¨ ·/min	¹ ö/%	Ó Ä Ÿ/%
0	95	5
10	60	40
60	60	40
61	25	75
66	25	75
67	95	5
77	95	5

72CX4ô @ 6 ÀG÷+LC-ELSD F >| Ä é# ² ; Ö 0ª"D Œ jM. F"D ×ELSD ð#{ ˜$Y Ö j 50 ÈE-"D » Ë 3.5 bar È Î,ú j 6 È8¢Ba ! j Dionex Acclaim® C30 Ä250 mm×4.6 mm È5 μm Å× ‰7x ¼2 IG·F >| ¼ s ß Ö#G7a È#G7a0; ¿ ²>˜ 2 È#qFO 1 mL/min È !$Y 30 Ä"é72 g ñ$æ@ ¾!" !'' Ä 10 mg/mL È F gGÿ 20 μL ÄTAG Y+X 7 ö ñF >| Ê W ÈG÷+X M'0 , 0 F# AÑ1Ç OPL • k TAG ,´-( ) [Gÿ Ä

1.3.6 » 6 ¦ N Ó e

69ç Ç,´ TAG +bGŸ F ÈG÷+GC-MS ð#{ 6 À k726ÚG¨4ô @ Ä

GC ' & ÖG÷+DB-WAX " 4ö1Ñ ! Ä60 m×

0.25 mm×0.25 m Å× ð#{ ˜$Y Ö 250 ÈF g $Y Ö 250 ÈE-"D j"V"D È#qFO 1.0 mL/min È 6#q" 1:20 ÈF g 1 L Ä w$Y0; ¿ ÖOÆ x X50 ; 1 1 min È'f > 22.5 /min ,´FO)· w$Y8# 175 È 0 > 4 /min ,´FO)· w$Y8# 230 È¦ 1 20 min Ä

MS 6 À ' & ÖEI +e/ë$À7-Gÿ j70 eV È/ë € $À ¼ PEÃ4ï$Y Ö 6 [j 230 ¼ 150 Ä › ÿ93 $ 30~500 m/z È$æ r &F 6 min Ä726ÚG¨,´ Ê W 6 À i ž 7 ö ñ ¼Ba Ã Ä NIST.08 ÅF >| È ÊGÿ 6 ÀG÷+X M'0 , 0 F# Ä

1.3.7 sn-2 » 6 ¦ N Ó e

X 6/ë Ç `,´ TAG ×(™] Ð • 1 mL 1 mol/L Tris-HCl 5C â#â pH l 8.0 Å 0.25 mL 0.05% 6 ö G¨ JÐ Ä P/V Å 0.1 mL 2.2% $CaCl_2$ Ä P/V Å 20 mg7 7 2 6ÚG¦ Ä$' 8(™ X40 —&ø w s3 min È'f > Ð • 1 mL 6 mol/L HCl ¼2 mL ‰GÊ È/ë ó Ä ‰GÊ+X "d .›G¨JÐ ¢(È"^"D:è 8# 200 L Ä"d@ ×(™ X;´ r .u7&8¢Ba ¯ : 6/ë È … 0$æ r j!" !'' / ‰GÊ ‰ G¨ Ä50:50:1 E/V/V Å6 sn-2 …+H"éGŸ,´ ' V ^ ¹ È +bGŸ F È ¦F >| ² : 1.3.6 pF GC-MS é# 6 À Ä sn-2 PA-( ) [Gÿ 9 ; ?AÑ1Ç Ö

$$\% = \frac{C}{3\times D}\times100\% \quad Ä2Å$$

´ / !

%k k 2 * • 6 sn-2 PA ½ ™ • 6) h Ó ô % "

C k k 2 * • 6 Ã h % "

D k k • 6 Ã h %d

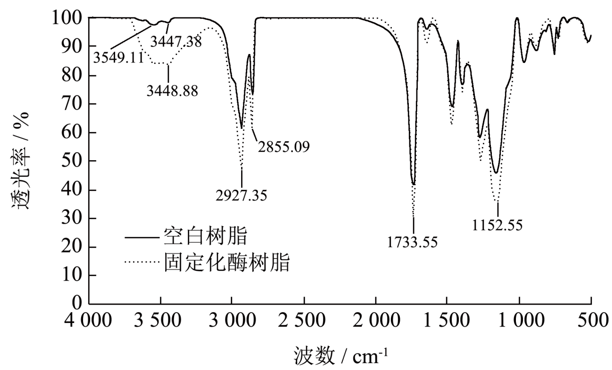
1.3.8 ô l Ó e

B P¼Gý 3!Q È p 9 žG÷+X £ w l f 7 ö B >˜/j Ä … 3P é 6 ÀG÷+X SPSS 26 F >| È 2 W 6 ÀG÷Duncan JGÿ93 $ ðP¼# Ä ý ÄM'B P¼ 6 ÀG÷+XEŸ & Design-Expert.V 8.0.6 Ä .(w5 fG÷+X EŸ &Origin 2018 Ä

5 Ò DAÞAð

2.1 固定化酶ANL-MARE的制备和表征

G÷+X FT-IR 6 À726ÚG¦ ANL-MARE * Ê F } >,´ A72 È ² . 2 p/j È k ƒ6<@0 È X ANL-MARE * Ê } > È A72 § 9-(l,´(© ± h f ÈF >˜ >G¦ * Ê F > A72,´ ¼4×5 ´ Z `.d • Ä ¦] ÈG¦ * Ê F >,´ A72 X 3 448 Ã2 927 Ã2 855.09 Ã 1 733 ¼1 152 cm-1 # K¯ 4 M'0 Î Ð ÄL¿-p * Ê F G¦ ANL X A72 : [Gÿ,´ Î Ð È h f 3 448 cm-1 Lt F n/j *,´ j h f j -OH ¼G¦(© 9,´ -NH- ×+O ,´ h5Y _ Ø [Ø >] Ä[@ Ø] 2 927 Ã2 855.09 cm-1 h f j $-CH_2$ F $-CH_3$ h5Y _ Ø [Ø >] È[@ Ø] > ANL > A72 @ Ï-(F Õ Ä h f 1 733 cm-1 _ -C=O- h5Y _ Ø È 1 152 cm-1 j C-N ,´ h5Y _ Ø È > { } Michael 1y[Ø >],´[@ Ø].D0¦5 Ì-(l È :5 ÌAñ Î ¶ ANL 7-FJE÷G 7*K^ ¼"RK^ Œ+X @ Ï > A725 8 Ä



* " / - . " 3 & &˘ B y :+°3¸ B uA] B

Fig.2 The infrared spectral changes before and after immobilization of ANL-MARE

) * Ê FG¦ ANL-MARE ,´<û,-E-Gÿ >G¦#k W 6 À ²>˜3 p/j È * Ê FG¦ ANL-MARE E-Gÿ j 13.97 mg/g È<û,-CX hLt)·Q E 92.37% È>˜ > * Ê F x)·E³Q Ä726ÚG¦>õE-Gÿ ¼G¦,´ hLt x)· ã ¾ A72,´" >˜M'0 ¼+¿"d W [Ø >] Ä[@ Ø]\.D0¦],´ A72) ANL hLt W7-Q ¾ x } ANL X #6Š3 5?),´ MP-64 A72 : § 9 83.79%<û,-CX hLt)·,´ ÕFƒ [Ø >] Ä[@ Ø] ANL-MARE ,´" #k ËEî 79.52 U/mg ÈQ ¾ x }.D 0¦ ÕFƒ,´ ANL X Þ„ ZIF-8 € É : f 7,´ * Ê FG¦ ,´G¦#k Ë [Ø >] Ä[@ Ø]5, : È * Ê FG¦ ANL-MARE G¦#k Ë 8Ÿ - È +X ¾ >5 G¦ Ü F ý Ä Ä

= &˘ BF¢ " / - . " 3 &+°;÷+' WFß õF¢"g S

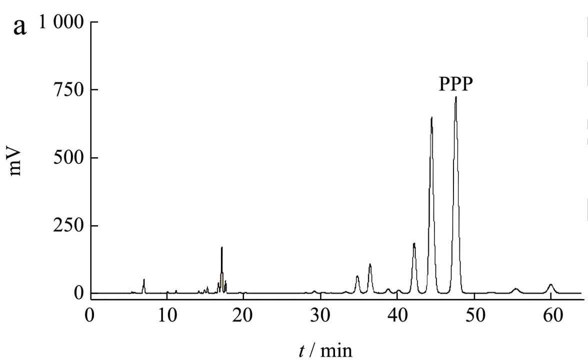
Table 3 Protein content and enzymatic activity of immobilized enzyme ANL-MARE

³	ANL-MARE
ñ B) { h/(mg/g … G $)	13.97 •0.46
ñ B) k Ñ/%	92.37 •0.08
' c O/(U/mg)	79.52 •2.53

2.2 PPP的富集及分析

x }.D0¦ ÕFƒ È58 ¸.œ72] [9 ` ü,´ PPP[Ø >] ÄP[@ Ø]P _ 8 @ 2- ¸G¨GŸ,´8Ÿ - Å(™ •$À È !" È9ç Ç WGÿ,´ PPP Œ j ý Ä Å(™ È _G¦# 8 @ OPL,´ £K^!•PÔ Ä \B P¼G÷+X$æ r#) ¸.œ72]

PPPF >| 6 üLö È Y+X PPP X IGž],´$æ@ Ö ~ ¾ ¦ =O¡ ¼726ÚG¨TAG ,´ WCX È X$æ r] À * 5 ¦ È þ6<Eî ` 6/ë,´- ,´ Ä5 Ì ² . 3 È4ÿE÷ 6 È ×(™ ] PPP-( ) [Gÿ þ 6 },´ 42.84% Q ` 94.43% Ä) 6 ×(™,´726ÚG¨4ô @F 0!• 6 À Ä>˜ 4 ÅÈ ×(™] k PA ¼sn-2 PA-( ) [Gÿ 6 [j 92.80% ¼90.03% È-(" üLö PPP { } 6 [Q ¶ 21.42% ¼27.17% Ä > x } Wang1y Ã Þ1y G÷ +X$æ r# üLö 6 PPP,´.D0¦5 Ì-(l Ä :5 Ì >˜ > È 6 ×(™] TAG k?± j PPP È!" 6 8ª 9 x üLö ¸.œ72] PPP È Œ j >5 OPL,´ G¦# 8 @,´8Ÿ - Å(™ •$À Ä



* 1 1 1 +°łKòö - $ & - 4 % "Ŗ$ 2 …

Fig.3 Enrichment of PPP and LC-ELSD liquid phase analysis

_! a 58 §• ÷ LC-ELSD D V Í " b <¶ Ó " ,) ! ^ LC-ELSD D V Í " c Ó " ,• PPP Ã h - $ d

= 1 1 1 2 üłKòy :+℃6.5Ð⁄ , T O 6.5Ð⁄3ð<

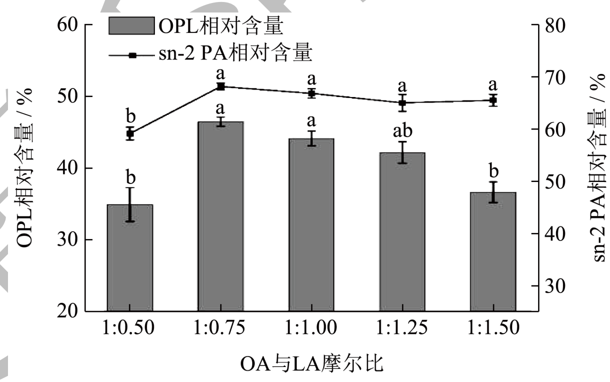
Table 4 Fatty acid and sn-2 fatty acid composition of palm stearin after fractionation

FA	,•		,	
	™FA	sn-2	™FA	sn-2
C12:0	0.23 •0.05	0.18 •0.59	0.02 •0.01	k
C14:0	2.12 •0.12	0.96 •0.23	0.78 •0.03	1.47 •0.18
C15:0	0.09 •0.01	k	k	k
C16:0	71.38 •0.78	62.86 •0.54	92.80 •0.28	90.03 •0.59
C18:0	3.92 •0.49	3.32 •0.63	3.94 •0.34	3.80 •0.73
C18:1	18.28 •0.56	27.07 •0.19	1.92 •0.12	4.27 •0.28
C18:2	3.98 •0.23	5.62 •0.13	0.53 •0.04	0.43 •0.22

_! FA ! » 6 - s Ã h " sn-2 !sn-2 * » 6 - s Ã h d

2.3 酶促酸解法合成OPL的单因素优化

2.3.1 OA 0LA i š ' s æ NOPL õ ¹



* 0 " : - " @! %F¢ ïF⁄? " 4 < 0 1 - +° ø

Fig.4 Effect of OA/ LA molar ratio on the synthesis of OPL by enzymatic acidolysis

_!M - ½ " { ¶ µ Ó ¡ W P Ø0.05 • ½ d

… 3PB P¼63 4 ý Ä 3P) OPL • k TAG ,´-( ) [Gÿ ú sn-2 PA-( ) [Gÿ,´ ¡ ý ÄG¦# 8 @ ý Ä5 • ÈG÷+X.á# 7aL" ×(™]E÷Gÿ,´726ÚG¨ 6/ë TAG È9ç Ç7aG¨ > ×(™],´ TAG Ç)· Eî 90.40% È !" \.D0¦G÷+X.á# 7aG¨ 6/ë9ç Ç TAG Ä sn-1,3 }(© W726ÚG¦ Ü F 8 @OPL & È726ÚG¨G * Ë ƒ OA ¼LA ,´" » _ ¡ ý ×(™72CX5 ´,´ k?± 3P ÈB P¼OÆ x63 Å(™OA > LA ™ D") G¦# G¨@ 8 @OPL ,´ ¡ ý Ä ² . 4 p/j ÈOA > LA ™ D" j 1:0.75 & ÈOPL ¼sn-2-PA-( ) [Gÿ n:‡ Î Ð È OPL þ 34.90% n:‡ Î Ð8# 46.43% ÄP Ø0.05Å sn-2 PA-( ) [G ÿ E î68.08% ÄOA > LA ™ D" j 1:0.75~1:1.5{L$ ÈOPL -( ) [Gÿ x ;L}C» ï È D 4 ™ D" ; ×(™ sn-2-PA-( ) [Gÿ"Ñ 9 n:‡ 2 Ä P Ú0.05 ÅÄ :5 Ì @ Gú j ƒ k72

6ÚG¨,´ [Gÿ 0 Ê & È OA > LA ")·CºQ J Î Đ OA ,´ •)· È C ,8$ ×(™] OPO [Gÿ Î Đ È6< OA > LA ")·E³ ~ & È I C+O @ WGÿ,´ LPL 72CX Ø > È@Ø T /ý õ å w J ¯ ×(™] OPL Ç)·L} ~ Ä !" ÈF9 OA > LA ™ D" j 1:0.75E³ jF2 Ì Ä

2.3.2 ^ i š ' s æ NOPL õ ¹

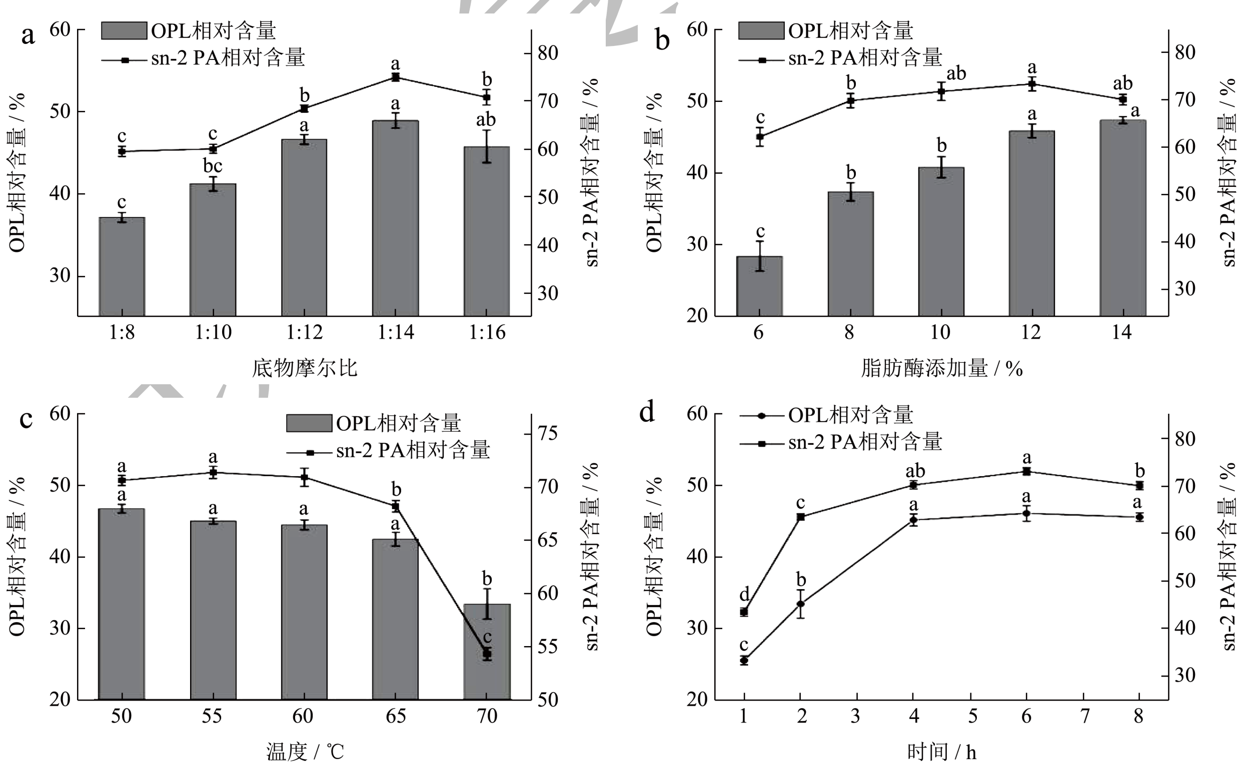
63 Å(™ PPP >726ÚG¨G * Ë ƒ,´ ™ D")G¦ # G¨@ 8 @OPL ,´ ¡ ý Ä ² . 5a p/j ÈPPP >72 6ÚG¨ ™ D" j1:8~1:14 & ÈOPL -( ) [Gÿ ¼ sn-2 PA -( ) [Gÿ n:‡ wQ Ä P Ø0.05 ÅÄ ƒ5 5 Î Đ ™ D " 8# 1:16 & È 8 @OPL -( ) [Gÿ"Ñ 9 n:‡ F È D sn-2 PA-( ) [GÿL} ~ È 7- _G * +O }0+ p 8$ Ä X F6 ý Ä] ÈQ Å(™ ™ D" Î ĐG¦ > Å (™,´.à ÎNÁ)· Ø > È Î@Ø Đ Å(™]$h/ë726ÚG¨,´Gÿ Q G * Ä726ÚG¨ Å X sn-1,3 },´ •)· Ä'f6<E÷ J,´726ÚG¨ 7- J Î Đ ý Ä ƒ3+,´G¨ Ö ¼2È W È þ 6< Á f726ÚG¦,´#k W ÈL} ~ PCXFO)· ÈF 05 Ì > Michael 1y Ø > .D0@Ø ¦5 Ì-(2« I Ä < & Å(™] $ J,´ 726ÚG¨ C Î Đ >5 726ÚG¨7aL",´Lî Ö Ä5, : pF È F9 ™ D" 1:14E³ j 8F2 Ä

2.3.3 » ANL-MARE ¦ h s æ NOPL õ ¹

63 726ÚG¦$+ ĐGÿ)G¦# G¨@ 8 @OPL ,´ ¡ ý È ² . 5b /j ÈANL-MARE +XGÿ 6%~12% ÈL¿-p G¦Gÿ,´ Î Đ ÈOPL -( ) [Gÿ n:‡ Î Đ ÄP Ø0.05 Å 'f6< È5 5 Î Đ ` 14% ĐG¦Gÿ >12% -(" È 8 @ OPL -( ) [Gÿ"Ñ 9 n:‡ 2 Ä P Ú0.05 Å sn-2 PA -( ) [GÿL¿G¦Gÿ,´ Î Đ x)à * x Î Đ >C» ¾ £>' È +J8# X ĐG¦Gÿ j 14% & § 9L} ~,´C» ï Ä :5 Ì @ Gú j ÈX Å(™Gÿ 0 Ê,´ õ å ; ÈĐ • $ J,´726ÚG¦ È Î Đ ¶ Å(™ >G¦#k W] ó,´ Õ@ È OPL +O @Gÿ n:‡ Q Ä ƒ ý ÄC» ¾ £>' & È5 5 Î Đ726ÚG¦) OPL ×)·,´ Q Œ+XE³ ? È6< sn-2 PA-( ) [Gÿ,´ ;L} 7-+a ¾E÷Q ,´ ĐG¦Gÿ È ý ÄE÷0;] *)àG * }0+ p 8$ Ø > Ä@Ø ! È5, 863<• ÈF9 726ÚG¦$+ ĐGÿ j 12% Ä

2.3.4 ± ë 1 g s æ NOPL õ ¹

63 ý Ä$Y Ö)G¦# G¨@ 8 @OPL ,´ ¡ ý Ä +a . 5c . È X 50~60 {L$ È OPL -( ) [Gÿ ú sn-2 PA-( ) [Gÿ"Ñ 9 n:‡ 2 Ä P Ú0.05 Å L¿-p$Y Ö Î Đ8#65 Èsn-2 PA -( ) [Gÿ n:‡L} ~ ÄP Ø0.05 Å X 70 & ÈOPL -( ) [Gÿ ¼sn-2 PA -( ) [Gÿ w n:‡L} ~ ÄP Ø0.05 ÅÄ } O.D0¦)à È * Ê FG¦ ANL-MARE ,´ 0F2$Y Ö jL$ X 40~60 Ø > ÈF@Ø 7-@ Gú ¶ \.D0¦ 50~60) 8 @ OPL-( ) [Gÿ 2 = W,´ Ï Ä+a ¾G÷+X ~ ¾ 50 $Y Ö # u 6$æ@ ý Ä Å(™ PPP È < &Q $Y J ×+O $ J,´7-6G È !" ÈF9 50 Œ j >5 ÎP¼ ' & Ä



* 9 8 ø À 2L %F¢ ïF/? " 4 < 0 1 - +° ø

Fig.5 Effect of different reaction factorson the synthesis of OPL by enzymatic acidolysis

2.3.5 ± ë ¨ · s æ NOPL õ ¹

63 ýÄ&L$)G¦#G¨@ 8@ OPL,´¡ýÈ². 5d Ä ý Ä &L$ 1~4 h µ ÈOPL -( ) [Gÿ ¼ sn-2 PA-( ) [Gÿ n:‡ wQ Ä P Ø0.05Å 4~6 hEî ` £>' È OPL -( ) [Gÿ ¼ sn-2 PA-( ) [Gÿ 2 = n:‡ Ä P Ú0.05Å ý Ä 8 h & sn-2 PA-( ) [Gÿ 9 pL} ~ Ä P Ø0.05Å F 7-+a ¾ ý Ä &L$ &K¯ È 6 € +OG *}0+ p8$ È F > Wang1y[Ø>],´5 [@Ø] Î 08$ Ä !" È5, 863<•F9 ý Ä &L$ j 4 h Ä

2.4 酶促酸解法合成OPL响应面结果及分析

* ¾ … 3PB P¼5 Ì È63 ANL-MARE G¦$+ ÐGÿ ÄÅ PPP >726ÚG¨,´ Å(™ ™ D" ÈÅ OA > LA ™ D" ÄC Å3 Z 3P È OPL -( ) [Gÿ Ä Y_1Å sn-2 PA-( ) [Gÿ Ä Y_2 Å j ý Ä l È *0û 3 3P 3"d £B P¼AîAÑ È § ƒAîAÑ ¼5 Ì?ñ>5 È) ÎP¼ ž F >| J s , 8 È Ç ` ¼!Q JN© , é0; Ö

$$Y_1=47.72+2.24A+0.88B+1.04C-0.16AB+0.02AC-0.56BC-2.89A^2-3.16B^2-3.38C^2$$

$$Y_2=72.46+1.58A+1.24B+0.12C-0.94AB+0.53AC-1.26BC-2.38A^2-2.98B^2-4.12C^2$$

= 0 1 -F¢" 4 < # P Y # F I O L F OA O,@Œ@˝ö3ÿ¨

Table 5 Box-Behnken experimental design and results

Ë r ¦	Ù -			Y_1	Y_2
	A	B	C		
1	0	0	0	48.18	73.01
2	1	0	-1	42.43	68.01
3	0	1	1	43.15	66.04
4	1	-1	0	44.01	68.93
5	1	1	0	44.37	68.77
6	0	0	0	46.81	72.17
7	0	0	0	47.49	72.02
8	-1	1	0	39.65	67.16
9	0	-1	1	41.44	65.34
10	1	0	1	44.41	66.76
11	-1	0	1	40.44	64.98
12	0	1	-1	42.04	67.91
13	-1	0	-1	38.54	64.11
14	0	0	0	48.49	72.46
15	0	-1	-1	38.09	62.17
16	0	0	0	47.61	72.62
17	-1	-1	0	38.65	63.56

i ž é 6 À5 Ì . Ä>˜ 6 ÅÈ , Q »,´ F lE³Q Ä F=32.69Å P l ± ~ Ä P Ø0.000 1 ÅÈ!" , Q » x ± n:‡"d £ ÄB Q »,´ ã Ê3+ Ä R^2=0.976 8 Å ¼ Q!" ã Ê3+ Ä R^2_{adj}=0.946 9 ÅE³ j*6 # ÈB$ >B Q »,´ ÎP¼B E³ ~ D 80; Ö8Ÿ - Ä!" F È a N©F l Ä F=2.33 Å ¼P l Ä P=0.215 6 Å>˜ > a N© = n:‡ È lB Q »,´0c Ê WE³ - È +X ¾ OPL,´ 8 @ ' &F >|N´#{ Ä i ž>˜] 4 3P,´ F l ¼ P l . È 0!QN© A ÃC)5 Ì ¡ ý ± n:‡ Ä P Ø0.01Å B)5 Ì ¡ ý n:‡ Ä P Ø0.05 ÅÈ ¼!QN© A^2 ÃB^2 ¼ C^2 ,´ Œ + X w x ± n:‡ Ä P Ø0.01 ÅÈ Ô Â N© AB Ã AC ÃBC)5 Ì"Ñ 9 n:‡ ¡ ý Ä P Ú0.05 ÅÄ 4 3P) 8 @ OPL -( ) [Gÿ,´ ¡ ýNª ¿ j Ö A ÚC ÚB È £ ÐG¦Gÿ ÚOA > LA ™ D" ÚÅ(™ ™ D" Ä

= 0 1 -,$ % WFß ø Å 3ÿ¨ å 2 …

Table 6 Variance analysis of response surface results fortherelativecontent ofOPL

º ÿW	< º ä	' g	ˆ º	F	P	¡ W ÿ
f ø	196.16	9	21.80	32.69	<0.000 1	**
A	40.23	1	40.23	60.34	0.000 1	**
B	6.16	1	6.16	9.24	0.018 9	*
C	8.69	1	8.69	13.04	0.008 6	**
AB	0.10	1	0.10	0.15	0.706 8	
AC	0.001 6	1	0.001 6	0.002 4	0.962 3	
BC	1.25	1	1.25	1.88	0.212 5	
A^2	35.06	1	35.06	52.58	0.000 2	*
B^2	42.06	1	42.06	63.08	<0.000 1	**
C^2	47.97	1	47.97	71.96	<0.000 1	**
÷	4.67	7	0.67			
ž ¥ »	2.97	3	0.99	2.33	0.215 6	â ¡ W
J b	1.70	4	0.42			
™ - Ó	200.83	16				
R^2	0.976 8					
R^2_{adj}	0.946 9					

g! * r ¶ µ Ó ¡ W P Ø0.05 ** r ¶ µ Ó ~ ¡ W P Ø0.01 d • ¶ ½ d

+a>˜7 é 6 À5 Ì . È , Q »,´ F lE³Q Ä F=64.40Å P l ± ~ Ä P Ø0.000 1 ÅÈ!" , Q » x ± n:‡"d £ ÄB Q »,´ ã Ê3+ Ä R^2=0.988 1 Å ¼ Q!" ã Ê3+ Ä R^2_{adj}=0.972 7 ÅE³ j*6 # ÈB$ >B Q »,´ ÎP¼B E³ ~ D 80; Ö8Ÿ - Ä!" F È a N© F l Ä F=3.72 Å ¼P l Ä P=0.118 5 Å>˜ > a N© = n:‡ È l B Q »,´0c Ê WE³ - È +X ¾ OPL,´ 8 @ ' &F >|N´ #{ Ä i ž>˜] 4 3P,´ F l ¼ P l . È 0!QN© A Ã B)5 Ì ¡ ý ± n:‡ Ä P Ø0.01Å C)5 Ì ¡ ý =

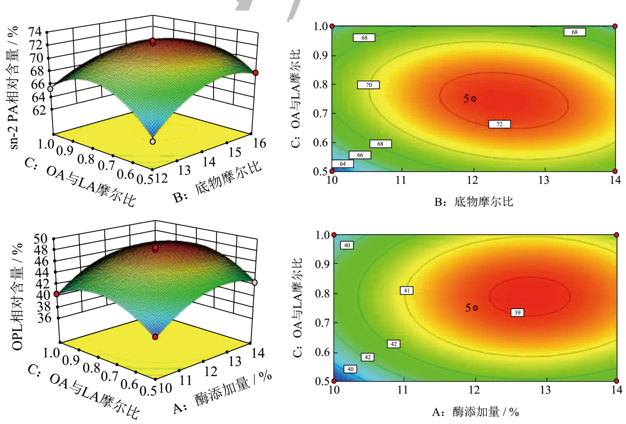
n:‡ ÄP Ú0.05 Å× Ô ÂN®BC)5 Ì ¡ ý ± n:‡ ÄP Ø0.01Å AB)5 Ì ¡ ý n:‡ Ä P Ø0.05Å AC)5 Ì"Ñ 9 n:‡ ¡ ý Ä P Ú0.05 ÅÄ ¼!QN@A^2 ÃB^2 ¼ C^2 ,´ Œ+X w x ± n:‡ Ä P Ø0.01 ÅÄ 4 3P) ×(™] sn-2 PA-( ) [Gÿ,´ ¡ ýNª ¿ j Ö A ÚB ÚC È £ ÐG¦Gÿ ÚÅ(™ ™ D" ÚOA > LA ™ D" Ä

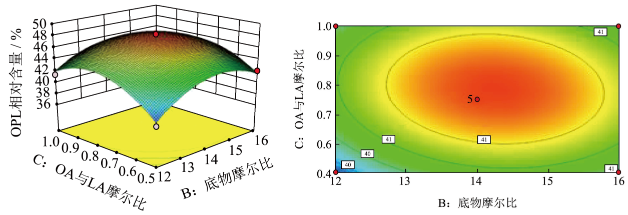
= T O 1 ",$ % WFß ø À 3ÿ¨ å 2 …

Table 7 Variance analysis of response surface results for therelative content of sn-2 PA

º ÿ W	< º ä '	g	ˆ º	F	P	¡ W ÿ
f ø	190.17	9	21.13	64.46	<0.000 1	**
A	20.03	1	20.03	61.11	0.000 1	**
B	12.20	1	12.20	37.22	0.000 5	**
C	0.11	1	0.11	0.32	0.587 7	
AB	3.53	1	3.53	10.78	0.013 4	*
AC	1.12	1	1.12	3.43	0.106 6	
BC	6.35	1	6.35	19.37	0.003 2	**
A^2	23.76	1	23.76	72.48	<0.000 1	**
B^2	37.28	1	37.28	113.71	<0.000 1	**
C^2	71.32	1	71.32	217.54	<0.000 1	**
÷	2.29	7	0.33			
ž ¥ »	1.69	3	0.56	3.72	0.118 5	â ¡ W
J b	0.61	4	0.15			
™ - Ó	192.47	16				
R^2	0.988 1					
R^2_{adj}	0.972 7					

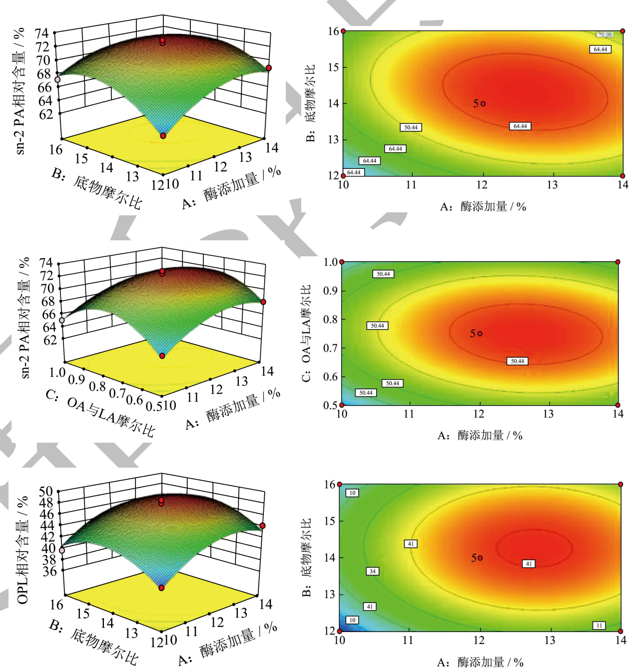
ý Ä "M' $ - ` 6 4 3P {L$,´ Ô Â Œ+X ?ö F È ² . 6 p/j È Ô Â Œ+XAB ÃAC ÃBC ,´ "4ï _ " È1yQ "4ï x] 6 ' Ä Ô Â Œ+X) sn-2 PA -( ) [Gÿ,´ ¡ ý ² . 7 p/j È BC Ô Â Œ+X "M' 0L' È D1yQ 4ï öLö È>˜ >BC Ô Â Œ+X)sn-2 PA-( ) [Gÿ,´ ¡ ý 0 j n:‡ È+a . 6 À Ô Â Œ+X W ? 6 [j Ö BC ÚAB ÚAC Ä





* ÌF¢Fß `' @! ,6.5Ö⁄ @! +° — ¾*T % 0 1 - ,$ % WFß+° ø À *

Fig.6 Response surface of the interaction of enzyme load, substrate ratio and fatty acids molar ratio on the relative content of OPL



* ÌF¢Fß `' @! ,6.5Ö⁄ @! +° — ¾*T % T O 1 " ,$ % WFß+° ø À *

Fig.7 Response surface of the interaction of enzyme load, substrate ratio and fatty acids molar ratio on the relative content of sn-2 PA

FJE÷ , Q »N´#{ È Ç ` 8 @ OPL 0F2 8ª j ÖPPP >726ÚG¨,´ ™ D" 1:14.27 È726ÚG¦$+ ÐGÿ 12.70% ÈOA > LA ™ D" j 1:0.76 È X!" ' & ;,´ 8 @OPL -( ) [Gÿ,´N´#{ l j 48.24% Èsn-2 PA( ) [Gÿ j 72.76% Ä X!" ' & ;F >| 3 !QP¼AñB P¼ Ç ` 8 @ OPL £ w [Gÿ j 47.93% Èsn-2 PA( ) [Gÿ j 71.69% È > Q »N´#{ l-(F È>˜ > ý ÄM' 8ª Q » 8 ÖE³ - È +X ¾ OPL G¦# 8 @,´ 7 , Ä

2.5 固定化酶ANL-MARE与商业酶催化合成OPL的比较

- } ¯# +X ¾72CX O ,´ v J F,´ sn-1,3(© 2 W * Ê F726ÚG¦NS40086 ¼ Lipozyme 435 X-(l ý Ä ' & ; È § 9E³ -,´ Ü F#k W Ä !" È X H F ,´ ý Ä ' & ; ÈB P¼ 6 ANL-MARE Ü F 8 @OPL ,´ Ü F#k W > v JG¦ NS40086 ¼ Lipozyme 435F >|" E³ È5 Ì ² . 8 p/j Ä3 /ý726ÚG¦ Ü F ý Ä] OPL-( ) [Gÿ ¼ sn-2 PA-( ) [GÿL¿-p ý Ä &L$,´ Î Ð6< Î Ð È ¦ X 4 h >C» ¾0c Ê Ä ¦] ÈANL-MARE ¼ NS40086 8 @OPL-( ) [Gÿ ú sn-2 PA-( ) [Gÿ"Ñ 9 n:‡ 2 Ä P Ú0.05Ä sn-2 PA-( ) [Gÿ w n:‡Q ¾ Lipozyme 435 ý Ä p Ç Ä P Ø0.05ÅD Lipozyme 435 X 4 h & OPL-( ) [Gÿ+J8# 9 p ;L} È B$ > ý ÄE÷0;] 7- ˆ XG * }0+ ÄF Ë5 ÌB$ > ANL-MARE ,´ Ü F#k W ¼sn-1,3(© 2 W > nQ ¾ Lipozyme 435 È ¦ Eî ` > NS40086 Ü F 8 @ OPL 7- Ë-(ƒ È ¦ 8 @ OPL ,´-( ) [GÿQ ¾ x }Q Þ 1y,´.D0¦G÷+XNS40086 0!•# Ü F 8 @ 42.07% OPL ,´ ÕF ƒ Ä5, : pF È * Ê FG¦ ANL-MARE § 9E³ H,´ Ü F 8 @ OPL ,´#k W Ä

* &˘ BF¢ " / - . " 3 & : r FF¢ ØB 4 < 0 1 - +°! Dfl
Fig.8 Comparison of immobilized enzyme ANL-MARE with commercial enzymes in catalytic synthesis of OPL

5 Að

\ · f 7 ¼>˜ ± ¶ * Ê F726ÚG¦ ANL-MARE È X $æ r ƒ 3+] È Ü F Å(PPP ÃOA ¼ LA 8 @OPL ÈFJE÷ … 3P ¼ ý ÄM' H F9ç Ç 0 H 8ª Ö PPP >726ÚG¨,´ ™ D" 1:14.27 ÈANL-MARE 726Ú G¦$+ ÐGÿ 12.70% ÈOA > LA ™ D" j 1:0.76 È50 ; ý Ä 4 h Ä X!" ' & ;,´ 8 @ OPL-( ) [Gÿ j 47.93% Èsn-2 PA-( ) [Gÿ j 71.69% Ä > v J * Ê FG¦-(" È ANL-MARE Œ j Ü F 8 @ OPL ,´+O(™ Ü F r & È § 9E³ H,´ Ü F#k W ¼ sn-1,3 }(© 2 W Ä \.D0¦ Ë ¶G¦# G¨@ 8 @ OPL ,´ à 8ª È j ê £ 72 / ñ,´ × J F f 7 • Ê ¶*6Aê *.p Ä

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