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Enzymatic esterification of tapioca maltodextrin fatty acid ester

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ABSTRACT

In this work new types of hydrophobically modified maltodextrin were prepared by enzyme-catalyzed reaction of maltodextrin and three fatty acids: decanoic acid (C-10), lauric acid (C-12) and palmitic acid (C-16). Lipase obtained from *Thermomyces lanuginosus* was found to be a useful biocatalyst in the maltodextrin esterification. Esterified maltodextrin with a degree of substitution (DS) 0.015–0.084 was prepared at the optimum conditions of 60 °C for 4 h. The DS was found to be at its highest when maltodextrin and fatty acids were taken in the ratio 1:0.5. The functional properties of these esterified maltodextrin were investigated. All esterified maltodextrin did not completely dissolve in water. Esterified maltodextrin at a concentration of 25% (w/w) exhibited Newtonian flow behavior similar to that of native maltodextrin. Esterified maltodextrin had a higher viscosity compare to native maltodextrin. X-ray diffraction pattern of esterified maltodextrin indicated crystallization of the fatty acid side chains. The thermal stability of esterified maltodextrin was checked by differential scanning calorimetry (DSC). Esterified maltodextrin was then used as an emulsifier to make *n*-hexadecane O/W emulsions. The emulsions were characterized according to their oil droplet characteristics and emulsification index.

1. Introduction

Maltodextrins have the same general formula as amylose but are of shorter chain length. Maltodextrins are widely used in industry due to their non-toxicity and low price. They are used as thickening agents in food processing, and as binding agents in pharmaceuticals (Biswas, Shogren, & Willett, 2009). Most polysaccharides are strongly hydrophilic and hence they are not surface active in emulsion. However, a small number of naturally occurring polysaccharides have some hydrophobic characteristics (e.g. gum arabic) or have been chemically modified to introduce non-polar groups (e.g. some hydrophobically modified starches) and these biopolymers can be used as emulsifiers (McClements, 2008). Maltodextrins also have some disadvantages. Due to the absence of lipophilic groups, maltodextrins are unsuitable for oil-in-water emulsion systems. With the development of food science and technology, attempts are being made to improve maltodextrin properties via chemical modification, hydrolysis processes, and production units (Zheng, Jin, & Zhang, 2007).

The introduction of an ester group into polysaccharide constitutes an important achievement because the ester group results in modifying the polysaccharides' original hydrophilic nature and obtaining amphiphilic polysaccharide. Amphiphilic polymers have hydrophilic and hydrophobic subregions, therefore they can act like low-molecular-weight surfactants and they may present good ability for oil emulsification probably due to steric stabilization with respect to their macromolecular structure (Sadtler, Imbert, & Dellacherie, 2002). Enzymatic processes offer an attractive alternative route for the synthesis of oligo- and polysaccharide esters. Selective processes catalyzed by enzymes may be performed under mild conditions of temperature and pressure, thereby avoiding polymer degradation (van den Broek & Boeriu, 2013). Enzymatic catalysis also reduces the use of toxic reactants. Enzymatic routes may be preferable because the chemical processes include extreme pH conditions, solvents that push the limits of acceptability for health (Alissandratos, Baudendistel, Flitsch, Hauer, & Halling, 2010). Enzymatic modification may be of interest for the synthesis of macromolecules with targeted food and biomedical applications (Kaewprapan, Baros, Marie, Inprakhon, & Durand, 2012). Presently there has been little research on enzymatic esterification of maltodextrin.

The purposes of the present study are: (a) to investigate optimum condition for esterified maltodextrin production by enzymatic esterification; (b) to study the physicochemical properties of

Abbreviations: Malto_D, maltodextrin decanoate; Malto_L, maltodextrin laurate; Malto_P, maltodextrin palmitate; DE, dextrose equivalent (dimensionless); DS, degree of substitution (dimensionless); n, flow behavior index (dimensionless); τ, shear stress (Pa); τ_0, yield stress (Pa); γ, shear rate (s^{-1}); k, consistency index (Pa s^n); M_w, weight-average molecular mass (g/mol); ΔH, transition enthalpy (J/g); T_m, melting temperature (°C); E_{24}, emulsification index (dimensionless).

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esterified maltodextrin; (c) to study emulsifying activities of esterified maltodextrin in *n*-hexadecane O/W emulsions.

2. Materials and methods

2.1. Materials

Tapioca maltodextrin of dextrose equivalent value of 16 was supplied by Corn Products Co., Ltd. (Bangkok, Thailand). The weight average molecular mass (M_w) was 5182 g/mol (Udomrati, Ikeda, & Gohtani, 2013) as measured by multi-angel laser-light-scattering (MALLS) (DAWN EOS, Wyatt tech. Corp., USA). Lipase obtained from *Thermomyces lanuginosus* (Sigma–Aldrich, Switzerland). Enzyme activity was about 100,000 U/g. Decanoic acid (C-10), lauric acid (C-12), and palmitic acid (C-16) were purchased from Sigma–Aldrich (Switzerland). All the other chemicals used were of analytical grade.

2.2. Esterified maltodextrin preparation

Maltodextrin and fatty acid in the ratio of 1:0.1, 1:0.5 and 1:1 (mole of D-glucose unit/mole of fatty acid) was used. Maltodextrin (1 g) was dissolved in 2 ml DMSO, 350 μl of lipase enzyme was added and incubated in waterbath at 50–70 °C. Incubation time was 2–8 h. Three fatty acids were investigated: decanoic acid, lauric acid and palmitic acid. The ester formed was precipitated by adding ethanol. The ethanol supernatant was poured off and three additional ethanol extractions were performed prior to drying of the precipitate in hot air oven at 50 °C.

2.3. Proton nuclear magnetic resonance (^{1}H NMR) spectra

The ^{1}H NMR spectra of the samples were recorded with a NMR (ALPHA 600, JEOL, Japan). The sample was dissolved in DMSO-d_6 and the solution concentration was 15% (w/w). The measurement was operated at 70 °C. All chemical shifts are reported in parts per million (ppm) using TMS as references, which is usually used as an internal standard for NMR measurements at elevated temperature. The ^{1}H NMR spectra of the esterified maltodextrin showed three protons of the terminal methyl group of the acyl chain, as a triplet, around 0.85 ppm. The peaks between 4.58 and 5.50 ppm corresponded to the signals from the four protons of the glycoside structure. The degree of substitution (DS) was obtained from the ratio of area of the proton peak at 0.85 ppm to that of the proton peak between 4.58 and 5.50 ppm, according to Eq. (1):

$$\mathrm{DS} = \frac{I_{\mathrm{Signal}}/3}{I_{\mathrm{AGU}}/4} \tag{1}$$

where 3 is the number of protons from the signal of the methyl proton, and I_{AGU} is the integral for the 4 protons of the anhydroglucose unit (AGU) between 4.58 and 5.50 ppm (Kapusniak & Siemion, 2007).

2.4. Interfacial tension

Interfacial tension between *n*-hexadecane and pure water containing esterified maltodextrin was measured by means of drop volume method employing a computer-controlled apparatus (DVS-2000, Yamashita Giken, Japan) at 25 ± 0.01 °C. The apparatus can automatically determine the *n*-hexadecane–water interfacial tension from the maximum volume of the pendant drop detached from the glass syringe immersed in the *n*-hexadecane.

2.5. Solubility

Esterified maltodextrin powder (30–50 mg) was suspended in 5 ml water, stirred for 30 min then centrifuged at 4000 rpm for 15 min. The supernatant was collected, dried in an oven at 90 °C and weighted. Solubility (%) was calculated as follows:

$$\text{Solubility (\%)} = \frac{\text{weight of dry supernatant}}{\text{weight of dry sample}} \times 100 \tag{2}$$

2.6. Rheological analysis

Shear stress (τ) and viscosity of esterified maltodexrin solutions of 25% (w/w) concentrations were measured using a cone and plate type viscometer. The samples were measured with a viscometer (DV-III Ultra, Brookfield, USA) using cone number CPE-40. The angle and the gap between the cone and plate were 0.8° and 13.0 μm, respectively. Samples were placed in the measurement cell of the viscometer and allowed to equilibrate at 25 °C. The shear stress of the sample was measured in the range of shear rate 5–225 s^{-1}. Experimental data was fitted to the Herschel–Bulkley model (Jafari, Beheshti, & Assadpoor, 2012; Nikovska, 2010) which is represented by the equation shown below:

$$\tau = \tau_0 + k \cdot \gamma^n \tag{3}$$

where τ is the shear stress (Pa), τ_0 is the yield stress (Pa), $\dot{\gamma}$ is the shear rate (s^{-1}), n is the dimensionless flow behavior index, and k is the consistency index (Pa s^n).

2.7. X-ray diffraction

X-ray powder diffraction was carried out using a Nano viewer (Rigaku Co., Japan). The powder samples were measured from 3° to 26° for 2θ.

2.8. Differential scanning calorimetry (DSC)

Transition enthalpy (ΔH expressed as J/g) and melting temperature (T_m) were determined by DSC (Diamond DSC, Perkin-Elmer, USA). Samples of esterified maltodextrin (8–10 mg) were sealed in Al pans and heated from −20 to 105 °C at 10 °C/min and rapidly cooled back to −20 °C. After cooling, samples were reheated immediately to 105 °C at the same heating rate. An empty pan was used as reference.

2.9. Emulsion preparation

Briefly, 6 ml of *n*-hexadecane oil were added to 4 ml of esterified maltodextrin solution (25% (w/w)) in a test tube and homogenized by high speed homogenizer (Ultra turrax T25, IKA Janke and Kunke, Germany) at 15,000 rpm for 1 min. Mean diameter of oil droplets and microstructure of fresh emulsions were determined.

2.10. Determination of average oil droplet size

The average diameter of oil droplets in emulsions was determined using a laser diffraction particle size analyzer (SALD-3000, Shimadzu Co., Ltd, Japan). This instrument measures the angular dependence of the intensity of light scattered from a dilute emulsion under stirring. To avoid multiple scattering effects, emulsions were diluted before measurement. Emulsions were stirred continuously throughout the measurement to ensure a homogenous dispersion of the emulsion droplets.

2.11. Microscopic analysis

A microscope (BX51, Olympus, Japan) was used to determine the microstructure of the emulsions at 20× magnification.

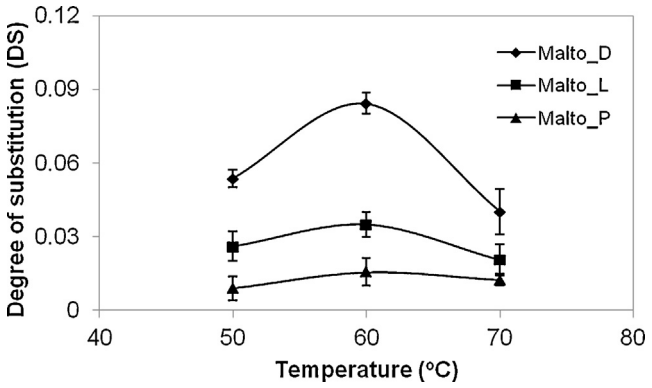

Fig. 1. Influence of temperature on the degree of substitution (DS). Reaction conditions were maltodextrin:fatty acid molar ratio of 1:0.5, reaction time of 4 h.

2.12. Emulsifying activity

The assay for emulsifying activity was modified from the method of Freitas et al. (2009) using *n*-hexadecane oil as the test substance. Emulsification was performed using a high speed homogenizer (Ultra turrax T25, IKA Janke and Kunke, Germany) at 10,000 rpm for 1 min. The aqueous phase was constituted of varied concentrations of esterified maltodextrin (0–35% (w/w)). After 24 h, the emulsification index (E_{24}) was determined as follows:

$$E_{24} = h_e/h_t \times 100$$

where h_e (mm) is the height of the emulsion layer and h_T (mm) is the overall height of the mixture.

3. Results and discussion

3.1. Esterified maltodextrin production

In Fig. 1, by increasing the reaction temperature from 50 to 60 °C, the DS of all esterified maltodextrin increased. Further increase in the reaction temperature from 60 to 70 °C caused the reaction efficiency to decrease. This result may be attributed that the enzyme lost its full activity by denaturation (Horchani, Chaâbouni, Gargouri, & Sayari, 2010). So we conclude that the optimum temperature for enzyme activity of the lipase used in this study was 60 °C.

The Fig. 2 shows that the DS reached a plateau after 4 h for maltodextrin decanoate and maltodextrin laurate, while the DS of maltodextrin palmitate reached maximum value after 2 h and did not decrease further even after 2 h. This result shows that esterification reaches a maximum at 4 h of reaction time for maltodextrin

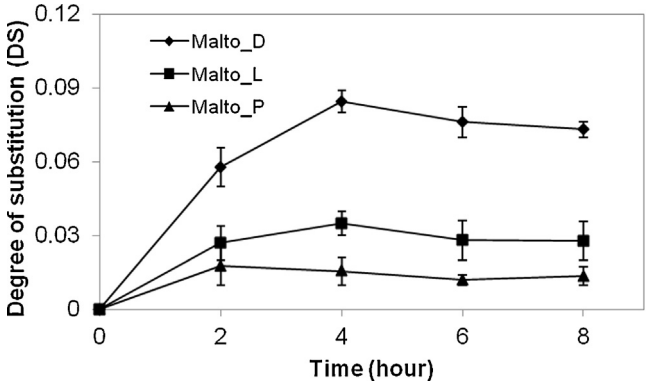

Fig. 2. Influence of reaction time on the degree of substitution (DS). Reaction conditions were maltodextrin:fatty acid molar ratio of 1:0.5, reaction temperature of 60 °C.

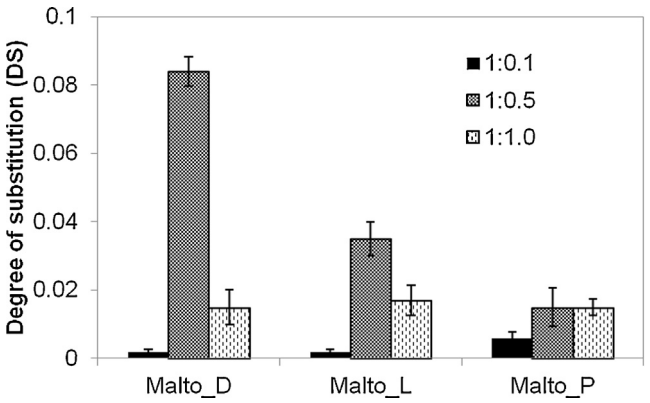

Fig. 3. Influence of maltodextrin/fatty acid molar ratio on the degree of substitution (DS) investigated at reaction condition of 4 h and 60 °C.

decanoate and maltodextrin laurate and 2 h for maltodextrin palmitate. The optimal conditions leading to the maximum of DS were at a temperature of 60 °C and reaction time of 4 h.

Fatty acids with 10, 12, and 16 carbons were investigated as acyl donors (Figs. 1 and 2). By increasing the fatty acid chain length, the DS decreased for all reaction conditions. These results may be due to the slower mobility of longer fatty acid chain length in the reaction system and consequently the rate of reaction of esterification was less than small fatty acid molecules.

The Fig. 3 shows that the DS was controlled by changing the maltodextrin/fatty acid molar ratio. The values of DS ranged from 0.002 to 0.084. In the case of maltodextrin decanoate and maltodextrin laurate, when the ratio of maltodextrin to fatty acid was 1:0.5, the DS value was the highest value. Moreover, it was found that the DS decreased as the ratio of maltodextrin to fatty acid reached 1:1. This result was possibly due to partial deactivation of the enzyme because of increasing acidity in the system. For maltodextrin palmitate with maltodextrin to fatty acid in the ratio 1:0.5 and 1:1, no differences of DS were observed, suggesting that similar results could be obtained using a higher dilution with less cost. These results show that DS of the products could be controlled by varying the reaction conditions, such as the reaction temperature, reaction time, and the concentration of the reactants. In the below investigation, the physicochemical properties were determined for the esterified maltodextrins prepared by the method at the optimum condition.

3.2. Physicochemical characterization

3.2.1. Interfacial tension

Interfacial tension of native maltodextrin and esterified maltodextrin solutions (25% w/w)/*n*-hexadecane system were measured at 25 °C. In Table 1, native maltodextrin showed interfacial tension of 47 mN/m. After esterification, interfacial tension was lowered to 39.68, 40.02, and 41.39 mN/m for maltodextrin decanoate, maltodextrin laurate, and maltodextrin palmitate, respectively. From the results of this study, it was found that maltodextrin esterification leads to increase the surface activity. This is

Table 1
Interfacial tension and solubility (%) in water of native maltodextrin and esterified maltodextrin.

Sample	Interfacial tension (mN/m)	Solubility (%)
Native	47.22 ± 0.28	100
Malto_D	39.68 ± 0.19	87.19 ± 1.28
Malto_L	40.02 ± 0.14	85.96 ± 1.27
Malto_P	41.39 ± 0.24	84.81 ± 2.09

a very important property because the greater the surface activity of esterified maltodextrin, the greater emulsification and emulsion stability. Therefore these results indicate the potential application of esterified maltodextrin in the preparation of O/W emulsion. The surface activity of esterified maltodextrin is obtained through enzymatic modification that introduces hydrophobic groups into the polymeric structure of the maltodextrin. The molecules of esterified maltodextrin could orient themselves at the oil–water interface and form an adsorbed monomolecular layer that is able to stabilize the emulsion by steric hindrance, and it is possible to produce stable emulsions.

3.2.2. Solubility

Solubility of native maltodextrin and esterified maltodextrins in water is shown in Table 1. The native maltodextrin was fully water soluble while all esterified maltodextrin was slightly insoluble in water. This result is consistent with Qiao, Gu, and Cheng (2006) who found that esterified starch has lower water solubility compared with the native starch. The decrease in water solubility was attributed to the lower amount of remaining hydroxyl groups in maltodextrin molecules after esterification. Esterification renders maltodextrin more hydrophobic, which would lead to reducing the possibility of hydrogen bond formation between hydroxyl groups in the maltodextrin and water, that is, by reducing solubility in water (Rajan, Sudha, & Emilia Abraham, 2008). As the chain length of fatty acid increases, the solubility of esterified maltodextrin in water tended to decrease. These results may be attributed to the fact that the solubility of the fatty acid in water decreases with increasing the chain length owing to the hydrophobicity.

3.2.3. Rheological properties

Rheological characteristics of native maltodextrin and esterified maltodextrin differed with the acyl donor used, as shown in Table 2. All esterified maltodextrin showed a slight increase in apparent viscosity at the shear rate of 225 s^{-1} and k compared to the native maltodextrin. Higher viscosity of esterified maltodextrin compared to that of native maltodextrin may be due to the increase in the resistance to flow of the larger molecules (Ibanoglu, 2002) and higher viscosity also might be related to internal plasticization (Rajan et al., 2008). Native maltodextrin does not have ester groups, so it may not show internal plasticization. This result is consistent with the results of Qiao et al. (2006) who found that esterified starch has higher viscosity compared to the original starch. The value of n is almost one in native maltodextrin which indicates Newtonian flow behavior. These results are consistent with the results of Dokic, Jakovljevic, and Dokic-Baucal (1998), Loret, Meunier, and Frith (2004), and Udomrati et al. (2013) who found that maltodextrin solution exhibits Newtonian flow behavior, regardless of concentrations. After esterification, there was no change in both the flow behavior and τ_0 for all esterified maltodextrin because there was no difference in the strength of attractive force in the systems. The increased viscosity of esterified maltodextrin adducts versus the native maltodextrin suggests that this material is a good thickener and perhaps can be used as emulsifiers and polymeric surfactant.

3.2.4. X-ray diffraction

X-ray diffraction of native maltodextrin and esterified maltodextrin are shown in Fig. 4a. The native maltodextrin showed a broad diffraction peak demonstrating the low crystalline nature. After esterification, the broad peak at about $2\theta = 20^\circ$ was apparent and this peak showed higher intensity compared to native maltodextrin. These changes are indicative of crystallites occurrence after esterification. The main peak of reflection of palmitic acid was shown in Fig. 4b, the most intense reflection was at about 20°. These results were consistent with those for lauric acid and decanoic acid (data not shown). The main peak of esterified maltodextrin was close to the most intense reflection for fatty acids (~20°). This result indicated that the molecular interactions between native maltodextrin and fatty acid were occurred.

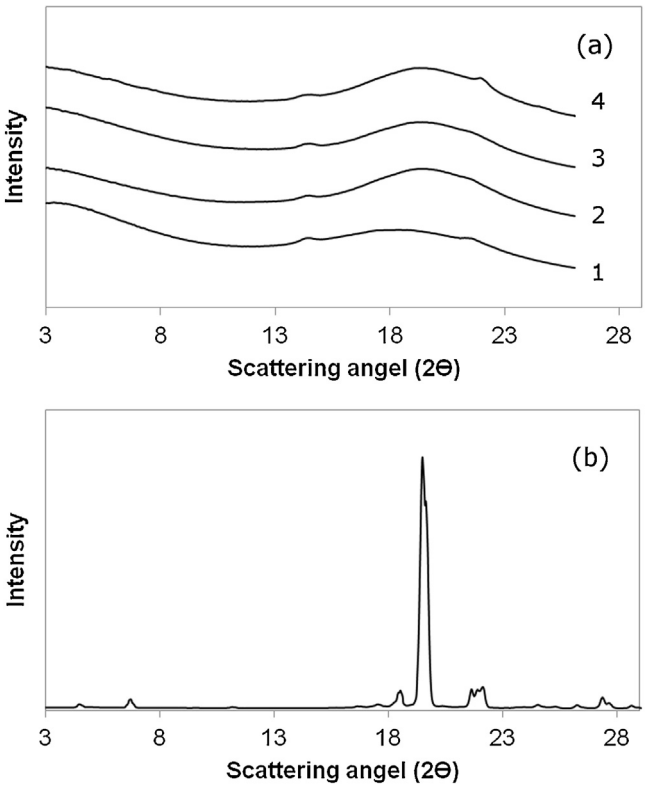

Fig. 4. X-ray diffraction of (a) native maltodextrin and esterified maltodextrin; native maltodextrin (1), maltodextrin decanoate (2), maltodextrin laurate (3), and maltodextrin palmitate (4); (b) palmitic acid.

3.2.5. Differential scanning calorimetry (DSC)

Differential scanning calorimetry thermograms for native maltodextrin and esterified maltodextrin are shown in Fig. 5. The first and second of heating scans, the broad melting peak were seen for

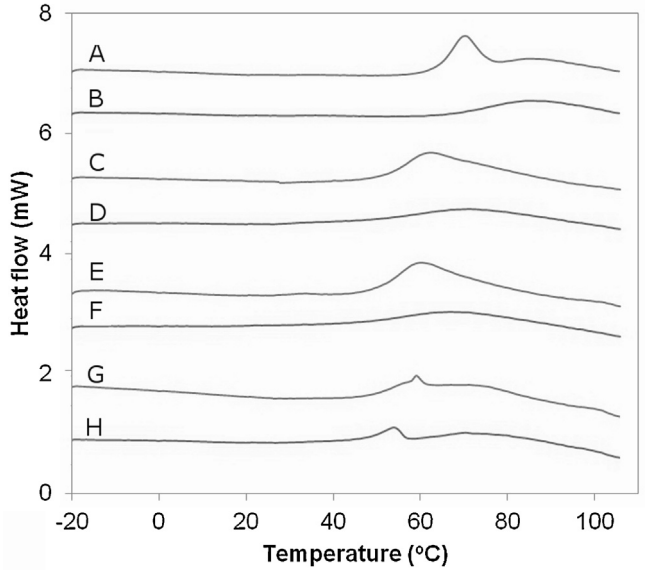

Fig. 5. DSC thermograms of native maltodextrin first heat (A), second heat (B); maltodextrin decanoate first heat (C), second heat (D); maltodextrin laurate first heat (E), second heat (F); maltodextrin palmitate first heat (G), second heat (H).

Table 2
Rheological characteristics of native maltodextrin and esterified maltodextrin solution at a concentration of 25% (w/w).

Sample	Apparent viscosity (mPa s) at 225 s^{-1}	n	k (Pa s^n)	τ_0 (Pa)
Native	4.62 ± 0.04	1.02 ± 0.01	0.0041 ± 0.0002	0.03 ± 0.00
Malto_D	5.18 ± 0.02	1.02 ± 0.01	0.0046 ± 0.0004	0.04 ± 0.01
Malto_L	4.92 ± 0.05	1.00 ± 0.00	0.0049 ± 0.0002	0.02 ± 0.00
Malto_P	5.59 ± 0.01	0.99 ± 0.01	0.0066 ± 0.0008	0.02 ± 0.00

all samples. Table 3 shows the melting transition data of native maltodextrin and esterified maltodextrin. Each maltodextrin sample was subjected to the scanning profile twice. For the first scan, the melting temperature (T_m) of native maltodextrin was 63.77 °C and that of maltodextrin decanoate, maltodextrin laurate and maltodextrin palmitate was 50.69, 50.36 and 47.50 °C, respectively which are lower than its unmodified maltodextrin. Those for the second heating scan were similar. These results may be attributed to the replacement of hydroxyl groups by long-chain fatty acids resulting in a decrease in the inter-molecular hydrogen bonds (Horchani et al., 2010). The T_m of esterified maltodextrin decreased with increasing chain length of the fatty acid used in esterification. These results concur with the results of modified starch reported in Sagar and Merill (1995). The increasing in fatty acid chain length may increase the free volume within the molecules due to the introduction of bulk groups which allowed more molecular mobility, also contributed to the reduction in the T_m (Rajan, Prasad, & Abraham, 2006). Both T_m and ΔH of the first scan are higher than those of the second scan for all esterified samples. These changes are due to slow relaxation processes accompanying recrystallization of the ester groups (Shogren, Biswas, & Willett, 2010). The ΔH reflects the energy required for disrupting the crystalline structure. DSC results show the ΔH of native maltodextrin (ΔH = 6.86 J/g), maltodextrin decanoate (ΔH = 7.35 J/g) and maltodextrin laurate (ΔH = 7.26 J/g) have a minimal difference. However, ΔH of maltodextrin palmitate was much lower than ΔH of native maltodextrin. The causes may be similar in above-discussed part, due to a decrease in hydrogen bonds between maltodextrin.

3.3. Emulsion forming and emulsifying behavior

3.3.1. Influence of esterified maltodextrin on emulsifying index

The emulsification index of native maltodextrin and esterified maltodextrin as a function of maltodextrin concentration was tested for *n*-hexadecane oil (Fig. 6). The emulsification index is an important parameter for evaluating the power of an emulsifier (Freitas et al., 2009; Neta et al., 2012). All esterified maltodextrin have proven to possess emulsion-stabilization capacity as shown by emulsification indices higher than that of the native maltodextrin. The high emulsification indices observed reflect the stability of the emulsions thus formed. No emulsion-stabilizing capacity, with emulsions breaking up after only a few second, was observed for native maltodextrin.

Table 3
Melting transition data of native maltodextrin and esterified maltodextrin.

Sample	First scan		Second scan	
	T_m (°C)	ΔH (J/g)	T_m (°C)	ΔH (J/g)
Native	63.77 ± 0.08	6.86 ± 0.08	69.46 ± 0.49	3.32 ± 0.16
Malto_D	50.69 ± 1.06	7.35 ± 0.46	51.67 ± 0.16	3.72 ± 0.17
Malto_L	50.36 ± 0.77	7.26 ± 0.06	48.24 ± 0.73	3.42 ± 0.18
Malto_P	47.50 ± 0.99	4.27 ± 0.05	47.86 ± 0.16	2.11 ± 0.38

Values are mean ± SD (n = 3).

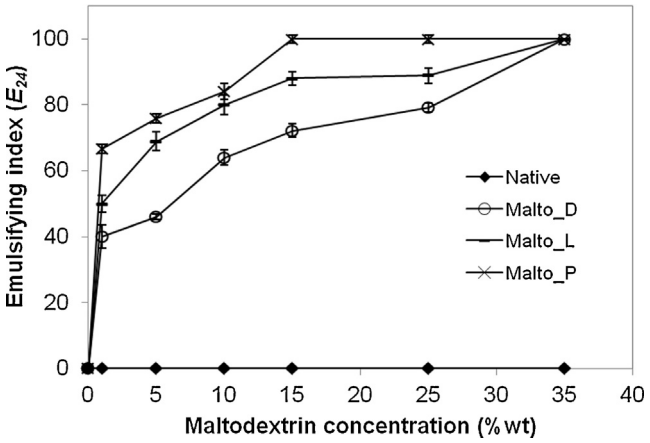

Fig. 6. Emulsification index as a function of maltodextrin concentration for *n*-hexadecane oil.

Emulsification index was further improved for higher esterified maltodextrin concentrations, reaching indices of 100% at maximal concentration of 35% (w/w) for all esterified maltodextrin. The effective emulsification index of emulsion was increased by increasing esterified maltodextrin concentration, since they are known to be able to cover more of the emulsion droplet surface. Emulsification index is higher when the carbon chain length is longer. The lengthy hydrocarbon tails grafted along the polysaccharide backbone may have stronger interaction with the oil surface. These data show that esterified maltodextrin may be used as stabilizers for dispersions of hydrophobic particles in aqueous medium. Their absorption at oil-water interface gives rise to the formation of a dense layer of hydrophilic loops providing steric repulsion between particle surfaces (Kaewprapan et al., 2012). So we conclude that maltodextrin that has been hydrophobically modified by enzymatic reaction with fatty acid has been shown to be surface active and to have emulsifying properties.

3.3.2. Influence of esterified maltodextrin on oil droplet characteristics

Native maltodextrin could not form any emulsion droplets hence there were no particles observed under the microscope as shown in Fig. 7. On the other hand, esterified maltodextrin formed O/W emulsions with particle sizes between 77 and 295 μm (Table 4). Maltodextrin palmitate produced an emulsion with the smallest oil droplets as well as the highest emulsion index (Fig. 6), indicating product better emulsifying ability. The oil droplet size was largest when maltodextrin decanoate was used.

Table 4
Oil droplet mean diameter of freshly prepared *n*-hexadecane O/W emulsions stabilized by esterified maltodextrin at 25% (w/w).

Sample	Mean diameter of oil droplets (μm)
Malto_D	295.52 ± 2.69
Malto_L	243.59 ± 4.14
Malto_P	77.71 ± 0.49

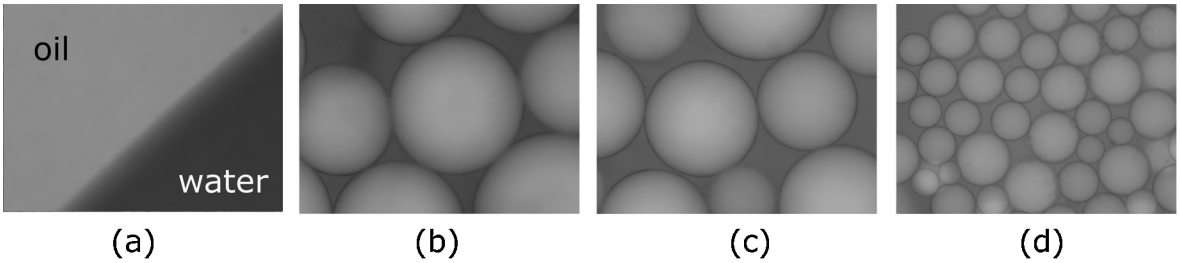

Fig. 7. Micrographs (20× magnification) of fresh *n*-hexadecane O/W emulsions stabilized by 25% (w/w) of native maltodextrin (a), maltodextrin decanoate (b), maltodextrin laurate (c), and maltodextrin palmitate (d).

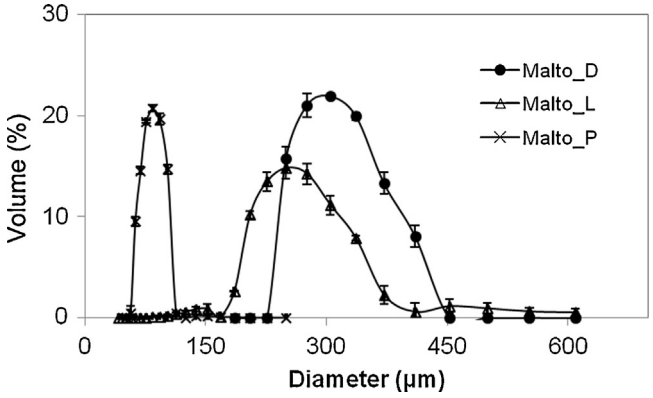

Fig. 8. Droplet size distribution of fresh *n*-hexadecane O/W emulsion stabilized by esterified maltodextrin. Data points are presented in average of three replications with maximum standard deviation of 5 μm.

The droplet size distribution of fresh emulsions, shifted to large droplet sizes as chain length of fatty acid decreased (Fig. 8). Emulsions particle size distribution was strongly dependent on the molecular weight of the fatty acid used for esterification of maltodextrin. The lower molecular weight fatty acid seemed to be less effective in stabilizing emulsions. Part of the effect may be due to the limitation of esterified maltodextrin with shorter fatty acid molecules on surface between oil and aqueous solution, which is disadvantage for inhibition of oil droplet coalescence and thus increases oil droplet size. The esterified maltodextrin with shorter fatty acid molecule is not sufficient for complete emulsion stabilization.

4. Conclusion

According to the findings of this research, it was concluded that esterified maltodextrin can be used as an emulsifier and stabilizing agent between aqueous solutions and hydrophobic compounds. The properties of esterified maltodextrin adducts depend on the degree of substitution and type of fatty acid. The esterification of maltodextrin with fatty acids has an effect on surface activity, hydrophobicity, rheological properties and emulsifying properties. The hydrophobically modified maltodextrin has improved these properties as compared to the native maltodextrin and may be used as an ingredient in applications where viscosity and hydrophobic interactions are desired. Enzymatic esterification is ecofriendly and avoids the use of nasty solvents. Therefore, enzymatically produced esterified maltodextrin can be used directly for various food applications.

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