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Maltodextrins from chemically modified starches. Selected physicochemical properties

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ABSTRACT

The aim of this work was to evaluate the effect of chemical modification of starch (cross-linking and/or stabilisation) on selected rheological and functional properties of maltodextrins of dextrose equivalent of 6, 11 and 16. It was found that values of glass transition temperatures were decreasing with dextrose equivalent of maltodextrin. The highest values of glass transition temperature (T_G) were determined for maltodextrin of DE 6-obtained from distarch phosphate and acetylated distarch phosphate. Increase in DE value of maltodextrin was also accompanied by decrease and increase in values of intrinsic viscosity and the critical concentration, respectively; however, there was no significant effect of kind of chemical modification of starch on the values of these parameters. Maltodextrin solutions at concentrations of from 10 to 70 % exhibited Newtonian flow behaviour. In the case of 50% solutions of maltodextrins of DE 6 the highest viscosity was produced by maltodextrin from native potato starch, while the lowest one by maltodextrin from acetylated starch. On the other hand, among the maltodextrin of DE 11 this one produced from acetylated starch showed the highest viscosity. All the maltodextrins exhibited surfactant properties in a water-air system, with the strongest effect observed for maltodextrins produced from double chemically modified starches and from acetylated starch. The surface activity was increasing with increasing of the DE value of maltodextrin. Moreover, values of surface tension were decreasing with increasing in maltodextrin concentration in the system.

1. Introduction

Maltodextrins are products of enzymatic degradation of glucosidic bonds of starch and are characterized by dextrose equivalent (DE) value of less than 20. They are a homogenous mixture of saccharides of a wide range of molecular masses (Sadeghi, Shahidi, Mortazavi, & Mahaladi, 2008; Yusraini, Hariyadi, & Kusnandar, 2013). The dextrose equivalent is a main parameter that characterises rheological and functional properties of maltodextrins. However, maltodextrins of the same DE value may exhibit different physicochemical properties, since they can be produced from starches of different botanical origin, and thus from starches of different structures and amylose to amylopectin ratios. Moreover there can be differences in parameters of enzymatic degradation of starch (Chronakis, 1998; Wang & Wang, 2000; Dokic, Jakovljevic, & Dokic, 2004; Pycia, Juszczak, & Gałkowska, 2015). Because maltodextrins are safe when used in food they have acquired the GRAS status (FDA, 21CFR 184). They exhibit advantageous filling, structuring, emulsifying and stabilising properties, as well as they are carriers of bioactive compounds (Chronakis, 1998; Wang & Wang, 2000; Pycia et al., 2015; Nurhadi, Roos, & Maidannyk, 2016). Maltodextrins as food ingredients has have been approved for using as texturizing agents and fat replacers (Chronakis, 1998; Sadeghi et al., 2008; Nurhadi et al., 2016). Maltodextrins are mainly

Abbreviations: DE, dextrose equivalent; DP, degree of polymerization; Mn, number average molecular weight; Mw, weight average molecular weight; T_G, glass transition temperature.

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used in production of dehydrated foods, since they reduce stickiness and improve firmness of such products. These properties of maltodextrins result from their water absorption ability, the ability to create a protective barrier on the surface of the absorbent particles, and ability to increase the glass transition temperature (Valenzuela & Aguilera, 2015). Despite numerous studies on the structure and potential application properties of maltodextrins, literature does not provide enough information about their rheological properties. In addition to a scientific importance, this kind of information can be useful in terms of designing of new food products. So far, enzymatic hydrolysis of starch has been performed on native starches of different botanical origin, such as potato, corn, wheat and banana, while there are little studies on maltodextrins produced from chemically modified starches. In a view of the proven effect of kind of chemical modification of starch on its physicochemical and rheological properties (Fortuna, Gałkowska, & Juszczak, 2004; Kaur, Sing, & Singh, 2004; Shon & Yoo, 2006) it can be assumed that there will be a corresponding effect of chemical modification of starch on the physicochemical properties of starch hydrolysates. The different character of chemical modification of starch is reflected in the properties of the resulting starch hydrolysates. In the previous study (Pycia, 2015) it was reported that there were significant effects of chemical modification of starch and of DE value of maltodextrin on oligosaccharide composition and molecular weight distribution of maltodextrins of the same DE value. It would be valuable to assess the effect of kind of chemical modification of starch and thus presence of additional chemical groups and bonds on rheological and functional properties of maltodextrins. Kędziora, Le Thanh, Lewandowicz, and Prochaska (2006) reported that products of enzymatic hydrolysis of oxidized and octenyl succinate starches showed higher surface activity as compared to their starch counterparts. The effect of chemical modification of starch on its surface properties has also been reported by Konował, Lewandowicz, Le Thanth-Blicharz, and Prochaska (2012), where hydrolysates of acetylated starch exhibited ability to decrease surface tension in water-air system, with the effect being dependent on the degree of substitution of starch. Expanding the knowledge about the physico-chemical properties of hydrolysed chemically modified starches can contribute to the search for their new application in food processing; however, the literature data on physico-chemical properties of maltodextrins produced from chemically modified starches are rather scarce. Therefore, the aim of this study was to evaluate the effect of cross-linking and/or stabilisation of starch on selected rheological, thermal and functional properties of maltodextrins produced from chemically modified starches.

2. Materials and methods

2.1. Materials

The materials were maltodextrins (M) of DE of 6, 11 and 16 produced from commercial native Superior Standard potato starch (PS), distarch phosphate (E 1412), acetylated distarch phosphate (E 1414), acetylated starch (E 1420) and acetylated distarch adipate (E 1422) (WPPZ S.A., Luboń, Poland) with use of BAN 480L bacterial (*Bacillus amyloliquefaciens)* α-amylase (Novozymes, Denmark) according to the procedure described in previous study (Pycia, 2015). A suspension of starch at a concentration of 30% (w/w) was treated with a dose of enzyme in an amount of 25 μl. Enzymatic hydrolysis of starch was carried out at 85 °C for a time experimentally determined in order to obtain starch hydrolysates with specified DE values of 6, 11 and 16. After completion of the reaction the enzyme was thermally inactivated. The product was freeze-dried using a Christ Alpha 1–2 LD lyophilizer (SciQuip Ltd, UK). Dextrose equivalent of the maltodextrins was determined by Schoorl-Regenbogen method (PN-A-74701:1978).

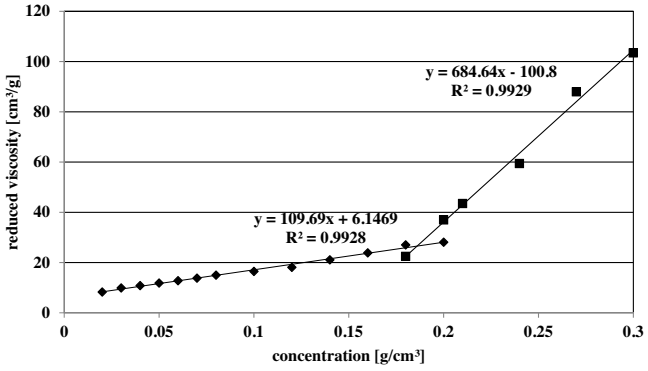

Fig. 1. Dependence of reduced viscosity on concentration of solution of maltodextrin of DE 6 produced from native potato starch.

2.2. Methods

2.2.1. Determination of glass transition parameters

The glass transition parameters were determined in DSC 204F1 differential scanning calorimeter (Phoenix, Netzsch, Germany). An aliquot of 3.5 mg of maltodextrin was weighted into aluminum pan and was heated from −50 to 250 °C with a rate of 10 °C/min. The reference sample was an empty aluminum pan. From the resulting thermograms the following parameters were determined: onset transition temperature (T_O, °C), midpoint temperature (T_M, °C), temperature at the inflection point (T_I, °C), end transition temperature (T_E, °C) and heat capacity change (ΔC_p, J/g·K). The measurement was performed in triplicate.

2.2.2. Determination of intrinsic viscosity and the critical concentration of maltodextrin

The intrinsic viscosity of each of maltodextrins was determined using Ubbelohde viscometer (K = 0.003197 mm^2/s^2) and electronic time measuring unit (ViscoClock, Schott Instruments, Germany). Maltodextrin solutions were prepared in 0.5 M KOH and their concentrations ranged from 0.01 to 0.40 g/cm^3. The measurements of flow time were performed in triplicate at 25 °C. On the basis of the dependency of the reduced viscosity (η_{sp}/c) on concentration (c), the intrinsic viscosity ([η]) and the Huggins constant (k') were determined using the Huggins Eq. (1), as follows:

$$\frac{\eta_{sp}}{c} = [\eta] + k' \times [\eta]^2 \times c \quad (1)$$

where η_{sp} is specified viscosity (cm^3/g), c is concentration of maltodextrin solution (g/cm^3), [η] is intrinsic viscosity (cm^3/g), k' is the Huggins constant.

The critical concentration was determined as the concentration at which the two curves of reduced viscosity vs. concentration intersected (Fig. 1).

2.2.3. Determination of rheological properties of maltodextrin solutions

Rheological properties of maltodextrin were examined in terms of determining flow curves and viscosities of maltodextrin solutions of various concentrations. For this purpose, solutions of maltodextrin of DE 6 at concentration of 10–50 $g/100\,cm^3$ and maltodextrins of DE 11 and 16 at concentrations of 30–70 $g/100\,cm^3$ were prepared as follows. Maltodextrin suspensions were heated in a water bath at temperature of 95 °C for 15 min at constant mechanical shearing (550 rpm).