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Original Article

Comparison of physicochemical and sensory evaluations of polymeric ONS utilizing tapioca maltodextrin DE7 or DE19 as carbohydrate source

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Abstract

Tapioca-starch maltodextrin (TM) has recently been developed for various Dextrose Equivalents (DE), which may influence the physicochemical characteristics of a product. This study aimed to develop nutritionally complete oral nutrition supplement (ONS) by using TM DE7 and DE19 as carbohydrate sources. Two polymeric nutritionally complete ONS formulas containing TM, whey protein isolate, rice bran oil, vitamins, and minerals, were developed. Their difference was that one contained TM DE7 and the other DE19. Physical properties and sensory acceptance were evaluated. Both formulas provided similar amounts of energy (255 kcal), 36 g carbohydrate, 10 g protein, and 9 g fat per 250 ml. ONS TM DE7 formula had a significantly ($p<0.05$) higher viscosity (34.48±0.85 cP) than DE19 (31.98±1.11 cP). There was no significant difference in pH between the ONS TM DE7 (6.31±0.05) and DE19 (6.29±0.07). In addition, there were no significant differences in palatability between the two formulas.

Keywords: oral nutritional supplement, tapioca-starch maltodextrin, dextrose equivalent, viscosity, polymeric formula

1. Introduction

Oral nutritional supplements (ONS) are specially processed or formulated foods that are intended for the dietary management of patients under medical supervision (Lochs et al., 2006). They are given to patients whose oral intake is insufficient to meet the altered nutrient requirements. Currently, various commercial ONSs are available in the market. They differ in composition, purpose, and form used, and can be classified into three types: nutritionally complete, nutritionally incomplete, and specific diseases ONS. Nutritionally complete ONS contains all macro- and micronutrients needed daily, including carbohydrate, protein, fat, vitamins, and minerals. Nutritionally incomplete ONS provides only specific nutrients, thus it cannot be the only source of nutrition, and is served only to complement the normal oral diet, whereas specific disease ONS provides nutrients for disease specific requirements. The selection of a suitable ONS is based on many factors, including individual nutrients and energy needs, gut functionality, mode of enteral access available, and diseases (Nelms & Sucher, 2019).

In an ONS formulation, carbohydrate accounts for 40-60% of total energy, thus, it is considered the major ingredient. Most of the ONS available on the market use maltodextrin as carbohydrate source (Malone, 2005) because

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it has low osmolarity, thus prevents osmotic diarrhea (Savino, 2018). Maltodextrin has been used safely for many years in the food industry. It is a partially hydrolyzed starch created by various hydrolytic processes using acid, heat and enzymes. In addition, these hydrolysis processes result in a mixture of relatively low-molecular-weight starch, dextrins, and glucose. The physicochemical and structural composition depends on the amount and type of processing used to treat the starch. A measurement of reducing power of starch-derived polysaccharides/oligosaccharides compared with D-glucose on a dry-weight basis is called Dextrose Equivalence (DE). Native starch has a DE of 0 and glucose has 100, while maltodextrin has a DE in the range 3-20. It is established that the higher the DE, the greater the extent of starch hydrolysis (Wang & Wang, 2000). Maltodextrins are highly water soluble and completely digestible in the small intestine. Because of the mildly sweet, bland taste, they could be used to enhance flavor, replace fat and increase bulking properties (Kulp, 2000). Corn, wheat, potato, and tapioca starch can be used as raw materials to produce maltodextrin. The amylose content, molecular weight, and chain length distribution of a starch can affect physicochemical properties to the maltodextrin (Hofman, van Buul, & Brouns, 2016). Currently, corn maltodextrin is the most common carbohydrate source in ONS production. However, tapioca maltodextrin (TM) is currently recognized as a potential source of carbohydrate in ONS. Based on a previous study, TM had lower amylose content than corn maltodextrin, therefore it may be easier to digest (Moore, Canto, Amante, & Soldi, 2005).

Tapioca maltodextrin is produced from controlled hydrolysis of tapioca starch by using acid-catalysis and/or enzymes (Lambri, Dordoni, Roda, & De Faveri, 2014). The characteristics of TM depend on the hydrolysis process. The longer the hydrolysis process, the higher the DE and lower the molecular weight (Hofman et al., 2016; Moore et al., 2005). While TM is an integral part of many processed foods, there is limited study information available on the use of TMs with different DEs in ONS formulations.

The present study has the following objectives: (1) to develop polymeric nutritionally complete ONS utilizing TM DE7 or TM DE19 as a carbohydrate source, (2) to compare the physicochemical properties of those two formulas, and (3) to evaluate sensory acceptability of the two formulas.

2. Materials and Methods

2.1 Materials

In the development of polymeric nutritionally complete ONS, whey protein isolate (WPI), rice bran oil, a vitamins and minerals premix, soy lecithin and flavor are considered the fixed ingredients. The only variable ingredient was maltodextrin DE7 or DE19, as a carbohydrate source. Each ingredient was purchased from the same suppliers to ensure the uniformity of the raw materials throughout the study.

Whey protein isolate was obtained by filtration to isolate the native protein. Protein content in WPI is 93.5 g per 100 g of powder. Eight essential amino acids, including branched-chain amino acids (BCAAs), and 10 semi-essential and other amino acids were included in the WPI. The fat source was obtained from rice bran oil. Each serving of rice bran oil (15 ml) contained 14 g fat which was composed of 3.5 g saturated fat (SFA), 6 g monounsaturated fat (MUFA), and 4.5 g polyunsaturated fat (PUFA), and was free from trans-fat and cholesterol. Micronutrients were inherited from premix of vitamins and minerals. Regarding macronutrient composition, of the total calories 50-55% were carbohydrate, 15-20% were protein and up to 30% were fat. The amounts of macronutrients and micronutrients contained in the developed ONS were calculated to match the adult-Thai DRIs.

2.2 Preparation of emulsion

Emulsion was prepared by dispersing TM, WPI, and vitamin and mineral premix into water and stirring for 20 min. Rice bran oil, soy lecithin, and flavor were added to emulsion and subsequently stirred for another 10 min. Homogenization was applied at 16,000 rpm for 3 min to reduce the fat particle size (Ultra-Turrax, Germany). Following homogenization, emulsions were pasteurized at 72^{o}C for 15 s.

Formula 1 consisted of 37 g of TM-DE7, 10.5 g of WPI, 8.5 g of rice bran oil, and 200 mg micronutrients premix. Trace amounts of lecithin and flavor were added to improve the emulsion stability and palatability. Formula 2 contained the same amount of each ingredient except for using TM-DE19 as the carbohydrate source. One serving of either formula provided 255 kcal, 36 g carbohydrate, 9.8 g protein and 8.5 g fat, with recommended amounts of micronutrients. The caloric distribution of carbohydrate: protein: fat was 55:15:30.

2.3 Physicochemical properties evaluation

2.3.1 Color measurement

Color was analyzed by using Chromameter Konica Minolta (Konica Minolta CR-400, Japan). The meter was calibrated with a white calibration plate (Y = 93.5, x = 0.3114 and y = 0.3190). The samples were poured into plastic cells, which were placed in sample holder. The measuring head of the meter was carefully placed on three different locations on the plastic cell. The measurements were made in triplicates. The recorded color coordinates L*, a*, and b* represent lightness, redness, and yellowness, respectively. The L ranges from black (0) to white (100), −a* = greenness and +a* = redness and −b* = blueness and +b* = yellowness. Data are presented as mean and standard deviation.

2.3.2 pH measurement

Each formula was examined in triplicate to determine the pH at room temperature using a pH meter (Mettler Toledo, Switzerland) placed directly into each emulsion. The pH meter was first calibrated according to the manufacturer's instructions, using buffer standards of pH 4, 7, and 10. Each developed formula was placed in a beaker, the pH meter was inserted, and the reading was recorded. The mean and standard deviation were then reported.

2.3.3 Viscosity measurement

The viscosities of the solutions were analyzed by using a rotational viscometer (Fungilab Premium Series, Spain). Spindle R2 was selected and speed of rotation was set at 200 rpm with a sample cup volume of 125 ml. The stainless-steel sensor was completely immersed into the emulsion and the measurement results were recorded. Measurements were recorded in triplicates. The mean and standard deviation are reported.

2.3.4 Sensory evaluation

Sensory evaluations were carried out by 39 healthy volunteers selected by invitation. Participants were informed of the details of the developed ONS and they voluntarily signed the informed consent before participating. This study was approved by the Research Ethics Review Committee for Research Involving Human Subjects, Chulalongkorn University.

On the sensory evaluation day, participants were seated individually at the cubicle in the sensory evaluation room and two formulas were served in 30 ml clear plastic cups at a cold temperature. Participants were asked to take a sip of water before tasting at least one sip of each sample. After tasting each sample, participants were asked to rate the appearance, smell, taste, consistency, viscosity, aftertaste, and overall acceptance, on a 9-point hedonic scale (1= dislike extremely, 2= dislike very much, 3= dislike moderately, 4= dislike slightly, 5= neither like nor dislike, 6= like slightly, 7= like moderately, 8= like very much, 9= like extremely) (Lawless & Heymann, 2013; Singh-Ackbarali & Maharaj, 2014). Participants were also asked to choose their preference between formula 1 (ONS TM-DE7) and formula 2 (ONS TM-DE19). Participants were allowed to write their comments down on the form, if any.

2.3.5 Statistical analysis

Data are presented as mean ± standard deviation (SD). Shapiro-Wilk test was performed to evaluate the distribution of the data. For normally distributed data, an independent t-test was used to analyze the differences between formulas. Meanwhile, Mann-Whitney U test was used to analyze the non-normally distributed data. *P*-value was set at 0.05 as threshold for calling significance. Statistical analysis was performed using SPSS 22.0 (IBM, USA).

3. Results and Discussion

3.1 Results

3.1.1 ONS development

The polymeric nutritionally complete ONS formulations utilizing TM DE7 or TM DE19 as a carbohydrate source were developed. Both TM DE7 and TM DE19 used in the current study provide 4 kcal/g. They are readily soluble in water and possess lower osmolarity than sucrose and glucose. Therefore, they may reduce the risk of osmotic diarrhea from the developed ONS (Zadák & Kent-Smith, 2009). Formula 1 contains TM DE7, whey protein isolate, rice bran oil, vitamins and mineral premix, soy lecithin and flavor. Formula 2 contains the same amounts of those ingredients except for using TM DE19 as the carbohydrate source. One serving of either formula provides energy (255 kcal), 36 g carbohydrate, 9.8 g protein, and 8.5 g fat. Macro and micronutrients compositions are shown in Table 1.

Table 1. Macronutrient and micronutrient compositions in 1 serving (250 ml) of developed ONS

Nutrient	Amount	Thai RDI (%)
Carbohydrate		
TM DE7 (formula 1) (g)	35.9	
TM DE19 (formula 2) (g)	35.9	
Protein		
Whey protein isolate (g)	9.8	
Fat		
Saturated fatty acid (g)	1.7	8.5
Monounsaturated fatty acid (g)	3.3	-
Polyunsaturated fatty acid (g)	3.0	-
Vitamins		
Vit A (mcg RE)	163	20
Vit D (mcg)	3.5	70
Vit E (mg alpha TE)	5	50
Vit K (mcg)	64	80
Vit B1 (mg)	0.6	40
Vit B3 (mg)	7	35
Vit B6 (mg)	1.6	80
Vit C (mg)	66	110
Minerals		
Sodium (mg)	68.1	3
Potassium (mg)	75.1	2
Calcium (mg)	55.2	7
Phosphorus (mg)	29.7	4

3.1.2 Physicochemical product characteristics

1) Color

Difference in DE used in ONS resulted in different colors. The ONS formula containing TM DE19 (formula 2) was significantly lighter than the formula with TM-DE7 (formula 1) (L* values 53.14 ± 1.80 and 46.11 ± 2.31, respectively, p=0.004). In addition, TM-DE19 (formula 2) was significantly more yellowish than the formula with TM-DE7 (formula 1) (b* 2.17 ± 0.22 and 1.58 ± 0.23, respectively, p=0.004). Data are shown in Table 2.

2) Viscosity

The developed ONS with TM DE7 (formula 1) had significantly higher viscosity than the formula with TM-DE19 (formula 2), namely 34.48 ± 0.85 cP and 31.98 ± 1.11 cP, respectively, with *p*-value <0**.**05**.** Data are shown in Table 2.

3) pH

There was no significant difference in pH between the developed ONS formulas (6.31 ± 0.05 and 6.29 ± 0.07, p-value = *0*.052). The ONS developed in our study are classified as having "low acidity" (AOAC, 2012). Data are shown in Table 2.

4) Sensory evaluation

Participants were healthy adults aged 22 to 71 years old (mean age 31.5 ± 10.8 years old). Most of the participants were females (59%). There was no significant difference in acceptability characteristics appearance, taste, smell, consistency, and aftertaste between formulas 1 and 2, as shown in Table 3. In addition, 51% of panelists in our study preferred the ONS with TM DE19.

3.2 Discussion

One serving (250 ml) of either polymeric nutritionally complete ONS provides 255 kcal. There was no difference in caloric distribution or nutrient composition in the formulas using TM-DE7 vs. TM-DE19: the energy values of these TMs are approximately equal at 4 kcal/g as underlined by international food law standards (Hofman et al., 2016).

The results demonstrate that incorporation of TM DE7 increased viscosity of ONS. This may be due to the higher percentage of polysaccharides with lower degree of polymerization (DP) in TM DE19. In addition, TM DE19 has a shorter chain of saccharides and narrower saccharide fraction distribution. The intrinsic viscosity of TM DE19 was therefore lower (Dokic, Jakovljevic, & Dokic, 2004). The viscosity for both formulas was aligned with most commercial liquid ONS available in the market. They can be also classified as thin liquids (less than 50 cP) according to National Dysphagia Diet Task Force (National Dysphagia Diet Task Force, 2002). The current study demonstrated that both TM-DE7 and TM-DE19 could be used as carbohydrate sources in an ONS. However, the pH of both the developed formulas were similar.

In addition, formula 2 was lighter in color and more yellowish compared to the formula with TM DE7. A previous study demonstrated that reducing sugar in carbohydrate may interact with amino groups in protein. This interaction may change the color of the formula. Tapioca maltodextrin DE-19 contains more reducing sugar, thus producing more interactions with amino groups in whey protein and forming a yellowish color. Moreover, this color formation can be accelerated by the heating during emulsion preparation (Kearsley & Dziedzic, 1995). The color of maltodextrin can also be influenced by the hydrolysis conditions involving acid, heating, and some time duration. The darker color of maltodextrin was caused by higher acidity, longer processing time, and higher temperature used in the production. The darker color formation during hydrolysis of maltodextrin is associated with caramelization reaction. However, in commercial production of maltodextrin, decolorization will be done in the final step to create white color (Trithavisup, Krusong, & Tananuwong, 2019).

The pH of developed nutritionally complete ONS utilizing TM DE7 and TM DE19 as carbohydrate sources were similar. In addition, the pH of our developed ONS was aligned with those on the market. The level of pH in ONS determines the solubility of protein, as well as interactions with other substances such as medications. Most ONS have about pH 6.8, which is close to neutral pH, while a lower pH may decrease protein solubility (Henriques, Miranda, Generoso, Guedes, & Jansen, 2017; Klang, McLymont, & Ng, 2013).

Table 2. Physical characteristics of nutritionally complete ONS with different DE maltodextrins

Physical characteristic	Formula 1 (TM DE7)	Formula 2 (TM DE19)	*p*-value
Color			
L*	46.11 ± 2.31[a]	53.14 ± 1.80[b]	0.004
a*	-0.83 ± 0.23	-0.74 ± 0.02	1.000
b*	1.58 ± 0.23[a]	2.17 ± 0.22[b]	0.004
Viscosity (cP)	34.48 ± 0.85[a]	31.98 ± 1.11[b]	0.001
pH	6.31 ± 0.05	6.29 ± 0.07	0.052

Data are presented as mean ± SD.
L* - brightness
a* - redness-greenness
b* - yellowness-blueness
[a, b] Different letters in the same row indicate significant differences (p-value <0.05)

Table 3. Hedonic ratings for developed ONS using TM DE7 and TM DE19

Hedonic parameter	Formula 1 (TM DE7)	Formula 2 (TM DE19)	*p*-value
Appearance	6.23 ± 1.40	6.38 ± 1.21	0.549
Taste	5.74 ± 1.63	5.85 ± 1.69	0.555
Smell	6.51 ± 1.78	6.67 ± 1.74	0.648
Consistency	6.33 ± 1.56	6.44 ± 1.54	0.715
Viscosity	6.15 ± 1.25	6.36 ± 1.33	0.313
Aftertaste	6.10 ± 1.59	5.95 ± 1.64	0.811
Overall acceptability	6.13 ± 1.51	6.08 ± 1.55	0.984

Data are presented as mean ± SD.

Oral nutritional supplements (ONS) are frequently prescribed for patients at risk of malnutrition. Palatability is thus an important factor to maintain long-term compliance. The semi-trained panelists in this current study reported similar sensory evaluations of appearance, taste, smell, consistency and aftertaste for the formulas with TM DE7 and TM DE19. Overall, the acceptabilities of those two formulas were similar.

4. Conclusions

Developed ONS containing tapioca maltodextrin (DE7 or DE19), whey protein isolate, rice bran oil, and vitamins and minerals premix, provides balanced and complete nutrition. The DE of TM used affected the physical characteristics of developed ONS. The formula with TM DE19 was less viscous but more yellowish than the ONS formula with TM DE7. Both developed ONSs were acceptable, while ONS with TM DE19 was more preferred by the panel participants. In addition, the abundance of cassava in most Asian countries, especially in Thailand and Indonesia, makes the TM cheaper than cornstarch maltodextrin, and therefore the production cost of the developed ONS can be competitive.

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