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Original Research Article

Functional properties of vegetable powder and the application in pudding for elderly

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ABSTRACT

Vegetables are well-known as a good source of dietary fiber, vitamins, minerals and bioactive compounds. However, their shelf-lives are very short and can easily loose its nutritional value after harvesting. Dried vegetables powder has gained interest and their properties greatly influence quality attributes of final products. This research aimed to study functional properties of three types of dried vegetable powder, i.e. sweet potato (SP), sweet corn (SC), and pumpkin (PK), which was used as the main ingredient for developing pudding for the elderly and the quality of the developed pudding was also measured. The functional properties of the dried vegetable were particle size and size distribution, water solubility (WS), water holding capacity (WHC), emulsion capacity (EC), emulsion stability (ES), and oil binding capacity (OBC). The size distributions of these three types of vegetable powder were in range between 10 to 100 μm. The PK powder had the highest WHC, EC and ES values followed by the SC and SP powder, respectively. In contrast, the PK powder had the lowest OBC value. The highest WHC, EC and ES values of the samples could be attributed to the highest dietary fiber content in the PK powder, thereby improving viscosity and texture, and also preventing syneresis of the final products. The highest amount of the vegetable powder which could be added separately into control formula of the pudding was at 8% (w/w). All developed puddings were accepted by thirty completely edentulous elderly panelists with overall acceptability score between like slightly to like moderately. These products can be used as a prototype of supplementary meal for elderly which have health benefits beyond basic nutrition, including, source of dietary fiber, antioxidants, and β-carotene.

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INTRODUCTION

Vegetables are rich in dietary fiber, vitamins, minerals and bioactive compounds (Brewer, 2011). However, vegetables are highly perishable and easily loose its nutritional value in a short period of time. Dried vegetable powder prolong the shelf-life and can be used as an ingredient in many food products, including beverages, salad dressings, bakery products and gluten-free diets. Furthermore, it can be also used as a functional food additives for improving the nutritional values of food products (Jiang and Zhang, 2013; Fitzpatrick and Lilia, 2005; Orsat et al., 2006; Marie et al., 2016).

The properties of vegetable powder used in food products are highly important because they affect the product attributes. Functional properties, such as particle diameter, water and oil holding capacity, emulsion capacity and stability, play an importance role in the physical and chemical properties during their preparation, processing, and storage (Mohamed et al., 1999). Changes in functional properties could be attributed to the modification of viscosity, texture, gelation, structure, and sensory attributes of the final products (Emine and Duygu, 2015).

Therefore, this research aimed to study functional properties of three types of dried vegetable powder, i.e. sweet potato (SP), sweet corn (SC), and pumpkin (PK), which were used as the main ingredient for developing pudding for the elderly and then the properties of the developed pudding were also measured. Pudding is nutrient-dense food composed of milk, egg and sucrose which provides protein, carbohydrates, fat, vitamins and minerals (Ares et al., 2009). Pudding has soft texture and easy to swallow so its texture is suitable for elderly who are completely edentulous (Elmore et al., 1999). However, the pudding has no dietary fiber which helps to maintain a healthy weight and lower risk of diabetes and heart disease (Anderson, Smith, and Guftanson, 1994). Vegetables are well-known as a good source of dietary fiber (Brewer, 2011). The addition of vegetable powder into the pudding also helps to increase the dietary fiber intake. Furthermore, the sensory acceptability of the vegetable pudding was also evaluated by completely edentulous elderly untrained panelists.

MATERIALS AND METHODS

Materials

Vegetable powders, including sweet potato (SP), sweet corn (SC), and pumpkin (PK) powder (Figure 1) were purchased from Chiangmai Bioveggie Co., Ltd. Thailand. Kappa-carrageenan was used as a gelling agent. Milk protein isolate, maltodextrin, and modified tapioca starch were certified as food-grade ingredients. Rice bran oil, soybean oil, and sugar were purchased from a local supermarket in Nakhon Pathom, Thailand.

Particle size determination

Particle size and size distribution of each vegetable powder was measured using a laser particle size distribution analyzer (Mastersizer 3000; Malvern Instruments Ltd., Worcestershire, UK). The results were reported as particle size distribution, surface-weighted mean particle diameter (D_{32}) and the volume-weighted mean diameter (D_{43}).

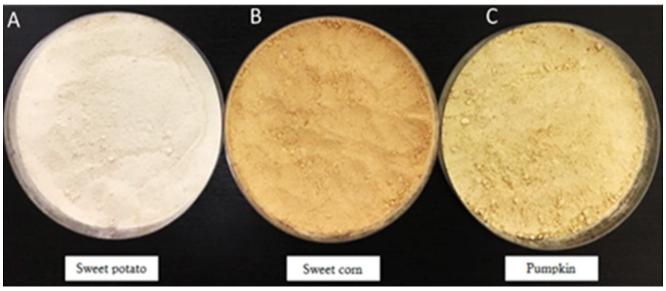

Figure 1. Photographs of sweet potato powder (A), sweet corn powder (B), and pumpkin powder (C).

Water solubility (WS) and Water holding capacity (WHC)

Water solubility (WS) and water holding capacity (WHC) of vegetable powder were determined according to the protocol of Koksel et al. (2008). One gram of vegetable powder was weighed into a pre-weighed centrifuge tube, added with 10 ml of distilled water, and then vortexed for 15 s every 5 minutes until 40 minutes. After 40 minutes of vortex, the samples were centrifuged using a centrifuge (model Z 400K; HERMLE Labortechnik GmbH, Wehingen, Germany) at 2100 rpm for 10 minutes at room temperature. The supernatant was dried using hot air oven at 100 °C for 2 hours. The precipitate was weighed and then dried using hot air oven at 100 °C for 2 hours. Water solubility (WS) and water holding capacity (WHC) were calculated as follows:

$$\text{WS \%} = \frac{\text{weight of dried supernatant}}{\text{weight of sample}} \times 100$$

$$\text{WHC (g/g)} = \frac{\text{weight of wet precipitate - weight of dried precipitate}}{\text{weight of sample}}$$

Emulsion capacity (EC) and Emulsion stability (ES)

Emulsion capacity (EC) and emulsion stability (ES) of vegetable powder were determined according to the protocol of Elkhalifa et al. (2005). One gram of vegetable powder was mixed with 50 ml of distilled water and 50 ml of soybean oil, and then homogenized using a high speed mixer (Ultra Turrax T18, IKA Works, Inc., Wilmington, NC, USA) at 13,500 rpm for 1.5 minutes. The mixture (40 ml) was divided into two 50-ml centrifuge tubes. One tube was centrifuged using a centrifuge (model Z 400K; HERMLE Labortechnik GmbH, Wehingen, Germany) at 4,000 rpm for 10 minutes at room temperature for evaluation the emulsion capacity. While, the other centrifuge tube was heated in a water bath at 80 °C for 30 minutes and then cooled to room temperature. After that, it was centrifuged under the same condition for evaluation the emulsion stability. Emulsion capacity (EC) and emulsion stability (ES) were calculated as follows:

$$\text{EC \%} = \frac{\text{height of emulsion layer}}{\text{height of whole layer}} \times 100$$

$$\text{ES \%} = \frac{\text{height of emulsion layer after heat}}{\text{height of whole layer}} \times 100$$

Oil binding capacity (OBC)

Oil binding capacity (OBC) of vegetable powder was determined le powder according to the method of Tiezheng et al. (2017). One gram (W_0) of vegetabwas weighed before placing into a centrifuge tube and weighed together (W1). Then 10 ml of soybean oil was added and vortexed for 5 minutes. The sample was allowed to stand at room temperature for 30 minutes, and then centrifuged at 3,000 rpm for 20 minutes. The supernatant was decanted and the centrifuge tube with precipitate was weighed (W2). Oil binding capacity (OBC) was calculated as follows:

$$\text{OBC (g/g)} = \frac{W_2 - W_1}{W_0}$$

Vegetable pudding preparation

The pudding without vegetable powder was prepared and used as a control (C). The recipe contained the following ingredients in percentage (w/w): milk protein (8.0), rice bran oil (1.0), maltodextrin (5.0), sugar (7.0), carrageenan (0.2), modified tapioca starch (0.4), and water (78.4). A single type of vegetable powder was used to formulate the flavor of each kind of vegetable pudding. The vegetable powder, including, SP, SC, and PK, were added separately at 8% (w/w). The preparation steps were as follows: firstly, the milk protein was dissolved in warm water, then left at room temperature for 30 minutes. Then, the vegetable powder was mixed together with milk protein before dissolving in warm water. Other dry ingredients, including, sugar, maltodextrin, and carrageenan were mixed well and dissolved in water, then left at room temperature for 30 minutes. After that, all the solutions were mixed together and rice bran oil was added. The mixture was then homogenized using a rotor-stator (model Ultra Turrax T25, IKA® Works, Inc., Wilmington, NC, USA) at 10,000 rpm for 2 minutes, and heated at 85-90 °C for 10 minutes. The mixture was packed into polypropylene (PP) plastic cup and covered with heat seal lid. These products were sterilized using a water spray retort at 118 °C for 33 minutes.

Sensory acceptability

Sensory acceptability of the vegetable pudding was determined according to Stone and Sidel (2004). Thirty untrained completely edentulous elderly panelists, who aged over 60 years old, were included for sensory acceptability testing. Appearance, color, hardness, taste and overall acceptability of all formulated vegetable pudding were evaluated using 5-point hedonic scale (1=dislike very much, 3=neither like nor dislike, and 5=like very much).

Statistical analysis

All parameters were performed in 3 replications. The results were reported as mean ± standard deviations. A one-way analysis of variance (ANOVA) with Duncan's multiple range tests was used to indicate the significance of differences ($p \leq 0.05$) among the mean values of each parameter. The statistical analysis was performed by using SPSS software for Windows version 22.0 (SPSS Inc., Illinois, U.S.A.).

RESULTS AND DISCUSSION

Particle size and size distribution

Particle size and size distribution of these three types of vegetable powder are shown in Figure 2. The particle size distributions of all vegetable powders were multimodal. The major diameters of SP and SC powder were in the range between 10 to 100 µm whereas PK powder was in the range between 100 to 1000 µm. The surface-weighted (D_{32}) and volume-weighted (D_{43}) mean diameters of the vegetable powder are reported in Table 1. The three types of vegetable powder expressed much higher D_{43} value than D_{32} value whereby D_{32} is more sensitive to the presence of small particle and D_{43} is more sensitive to the presence of large particle (McClements, 2005). The particle size of vegetable powder could be influenced by its processing, such as grinding process, and also the properties of raw material itself (Prasad et al., 2012). The particle size could affect functional properties of the vegetable powder, thereby influencing the properties and stability of final food products. Kraithong et al. (2018) suggested that the small particle size has high values of viscosity, water solubility and water holding capacity due to large surface area for water contact.

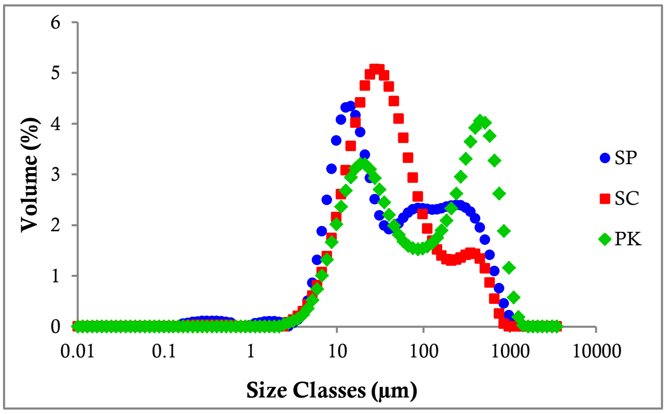

Figure 2. Particle size distribution of vegetable powders

Water solubility (WS) and Water holding capacity (WHC)

Water solubility (WS) and water holding capacity (WHC) of vegetable powder are presented in Table 1. There were significant differences ($p \leq 0.05$) among the different types of vegetable powder. The SC powder showed the highest value of WS while the PK powder showed the highest value of WHC. The high WS and WHC values may be due to the presence of some soluble components such as sugar and soluble fibers (Andrade-Mahecha et al., 2012). Consistent with Kaushal et al. (2012), the high WHC values of taro flour (1-2.5 g/g) can be attributed to presence of high amount of carbohydrates. They indicated that the flours with high WHC values may have more hydrophilic constituents, such as polysaccharides. In addition, soluble fibers have high hydration ability and form viscous solutions, thereby improving the stability and decreasing water separation from the product (Kaushal et al., 2012; Saura-Calixto and Goni, 2006). Hence, WS and WHC values of all three types of vegetable powder might suitable for using as main ingredient in developing the vegetable pudding and for improving the stability of the pudding after sterilization process.

Table 1. Functional properties of vegetable powder[1, 2]

Vegetable	D_{43}	D_{32}	WS (%)	WHC (g/g)	EC (%)	ES (%)	OBC (g/g)
SP	131.00±4.00^{b}	13.27±0.40^{c}	15.02±0.46^{c}	1.01± 0.01^{c}	2.50± 0.00^{c}	6.25± 0.00^{c}	1.11± 0.02^{a}
SC	92.13±2.41^{c}	23.03±6.01^{b}	40.38±0.49^{a}	1.28± 0.01^{b}	13.75± 1.25^{b}	50.42± 1.91^{b}	1.04± 0.01^{b}
PK	240.67±7.37^{a}	34.10±1.11^{a}	19.94±0.50^{b}	2.11± 0.02^{a}	52.92± 3.15^{a}	61.25± 2.17^{a}	0.98± 0.04^{c}

[1]Values are expressed as means ± SD (n=3).
[2]Different letters in the same column indicate significant difference at $p \leq 0.05$

Emulsion capacity (EC) and emulsion stability (ES)

Emulsion capacity (EC) and emulsion stability (ES) of the vegetable powder are shown in Table 1. There were significant differences ($p \leq 0.05$) in EC and ES values for all samples. The highest value of EC and ES values were found in PK powder. The high EC and ES values are probably due to the presence of high dietary fiber in this samples, which might have increased the viscosity of the aqueous phase and reduced the tendency of the dispersed oil globules to migrate and coalesce, thereby increasing the emulsion stability (Emine and Duygu, 2015; Abdul et al., 2012).

Oil binding capacity (OBC)

Oil binding capacity (OBC) of vegetable powders are presented in Table 1. The highest OBC was observed in SP powder which was significantly different ($p \leq 0.05$) from other samples. The high values of OBC may be due to high numbers for hydrophobic groups within molecules of this sample (Tharise et al., 2014). Ingredients with high OBC values can act as emulsifiers and also play an important functional role in improving viscosity and texture of formulated foods (Emine and Duygu, 2015).

Vegetable pudding formulation

Vegetable puddings were developed as a prototype ready-to-eat meal supplement for the elderly people. According to Table 2, the vegetable pudding did not only contain macronutrients, including carbohydrate, protein, and fat, but also contain antioxidant, carotenoids, and dietary fiber. It is clearly seen that the vegetable powder helped to increase the nutritional value, antioxidant activities, and carotenoid contents of the products. The puddings were sterilized using water spray retort to obtain the shelf stable product which could be stored at room temperature without any spoilage. In addition, they were packed in the PP plastic cup covered with heat seal lid which could protect them from light. Figure 3 shows the appearance of the control and three types of vegetable pudding used in this study.

Table 2. Nutritional value, antioxidant activities, and carotenoid contents of control and vegetable pudding

Composition	Formula			
	C	SP	SC	PK
Protein (g/100g)	1.96	3.12	3.02	3.01
Fat (g/100g)	3.12	2.71	2.76	3.03
Carbohydrate (g/100g)	15.22	15.35	14.43	15.09
TDF (g/100g)	0.00	0.46	0.98	1.60
Energy (kcal/100g)	-	98.30	94.62	99.70
DPPH value (µmole TE/g)	0.27	0.35	0.76	0.51
ORAC value (µmole TE/g)	3.80	6.67	6.95	6.54
TPC (mg GAE/g)	0.29	0.30	0.34	0.34
Carotenoid content (ug/g)	0.00	0.38	0.21	0.43

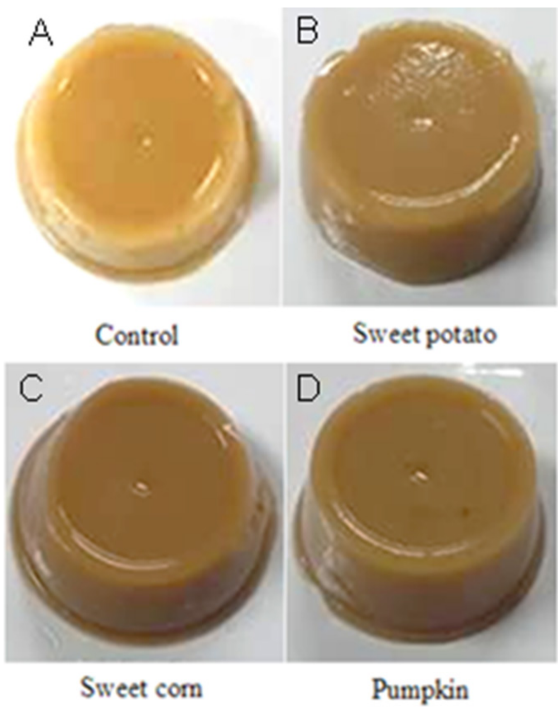

Figure 3. Photographs of control (A), sweet potato (B), sweet corn (C), and pumpkin (D) pudding.

Sensory acceptability of formulated vegetable pudding

The scores of sensory acceptability including appearance, color, hardness, taste and overall acceptability are shown in Table 3. There was no significant difference ($p \le 0.05$) among the mean values of appearance, taste and overall acceptability in developed products compared to the control. All vegetable puddings were accepted by completed edentulous elderly panelists with the mean score of overall acceptability at 4.1-4.5 (between like slightly to like moderately).The good functional properties including WS, WHC, EC and ES values of the vegetable powder could be attributed to high dietary fiber content in samples, thereby improving viscosity and texture, and also preventing syneresis or water separation of the final product (Kaushal et al., 2012). Addition of the vegetable powder improved the texture of the pudding, thus, the mean values of hardness of the developed pudding was significantly ($p \le 0.05$) higher than that of the control. In addition, the hardness value, obtained from texture profile analyzer (data not shown) of the pudding was increased when the type of the vegetable powder changed from SP, SC, and PK. The highest EC and ES value in the PK sample could be contribute to the strong and compact emulsion and gel structure (McClements, 2005) of the pudding, leading to the highest hardness value.

Table 3. Sensory acceptability score of control and vegetable pudding [1, 2, 3]

Formula	Appearance	Color	Taste	Texture	Overall acceptability
C	4.28 ± 0.68^{a}	4.24 ± 0.66^{a}	4.58 ± 0.58^{a}	2.73 ± 0.67^{c}	4.54 ± 0.25^{a}
SP	3.97 ± 0.81^{a}	3.79 ± 0.73^{b}	4.17 ± 0.95^{a}	4.33 ± 0.80^{ab}	4.23 ± 0.86^{a}
SC	4.27 ± 0.69^{a}	3.93 ± 0.83^{ab}	4.43 ± 0.73^{a}	4.53 ± 0.68^{a}	4.43 ± 0.73^{a}
PK	4.10 ± 0.96^{a}	4.10 ± 0.76^{ab}	4.23 ± 0.90^{a}	4.03 ± 0.96^{b}	4.17 ± 0.91^{a}

[1]Values are expressed as means ± SD (n=30).
[2]Different letters in the same column indicate significant difference at $p \le 0.05$
[3]The sensory acceptability was evaluated using 5-point hedonic scale.

CONCLUSIONS

Functional properties (WS, WHC, EC, ES and OBC values) of dried vegetable powder used in pudding is important to know beforehand as it to helps in improving viscosity and texture, as well as in preventing syneresis of the products. The development of the pudding with vegetable powder including sweet potato, sweet corn and pumpkin powder were well-accepted by the completely edentulous elderly. The vegetable pudding can be used as a prototype product which may help to improve the nutritional status and quality of life of the elderly or one who have chewing problems. The home use test will be further conducted and the information of nutritional status of the elderly before and after consuming the vegetable pudding will be collected in order to confirm that these products can be help to improve the nutritional status and quality of life of the elderly.

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