



Research article

Inhibitory effect of different varieties of mango peel extract on enzymatic browning in potato purée

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Abstract

Enzymatic browning is a main problem in fresh-cut fruits and vegetables. Recently, there is an increasing consumers and fruit and vegetable processors demand for using natural antibrowning agents. Therefore, the study investigated the enzymatic browning inhibition of potato purée by various varieties of mango peel extract. The results showed that the browning value of potato purée blended with mango peel extract from the Chok-Anan cultivar (CMPE) was lower than that blended with the extract from Nam-Dok-Mai (NMPE), the Kaew cultivar (KMPE) or distilled water (DW) during 1–6 hr of storage. The percentage browning inhibition of potato purée blended with CMPE was higher than that treated with NMPE or KMPE at 6 hr of storage. CMPE inhibited potato polyphenol oxidase (PPO) activity more than did NMPE and KMPE with percentage inhibition values of 47.16, 38.32 and 34.95, respectively. CMPE also had a high amount of total phenolics, similar to NMPE but higher than KMPE. The high PPO inhibition of CMPE might have been due to its high total phenolic contents. Therefore, CMPE could be utilized as a natural anti-browning agent in the potato processing purée industry.

Introduction

Mango (*Mangifera indica* L.) is one of the most important tropical fruits worldwide based on production and consumption (Maisuthisakul and Gordon, 2009). Mango is a seasonal fruit and is the most exported product in Thailand (Maisuthisakul and Gordon, 2009). Better known cultivars of mango grown in Thailand include Nam-Dok-Mai, Kaew and Chok-Anan (Maisuthisakul and Gordon, 2009). Mango is processed industrially into several products such as a purée, nectar, leather, pickles and canned slices (Loeillet, 1994). Mango peel is the major waste (7–24% of the total weight of mango fruit) during the commercial processing or consumption of the fruit (Iqbal et al., 2009; Kim et al., 2012). However, the amount of mango peel waste depends on processing. Mango peel is a good source

of polyphenol, carotenoids, dietary fiber, enzymes, vitamin E and vitamin C, and has good antioxidant properties and benefits for human health (Ajila et al., 2007).

Potato is a popular vegetable and is one of the most important food crops (Sukhonthara and Theerakulkait, 2012). Black and brown spot discoloration of potato caused by surface tissue damage during handling, storage and processing result from the enzymatic browning reaction or polyphenol oxidase (PPO; Sapers et al., 1989; Cacace et al., 2002). Boonsiripiphat and Theerakulkait (2009); Kaewka et al. (2009) found that the PPO activity in potato was inhibited by rice bran extract. Sukhonthara et al. (2016) reported that protocatechuic acid, vanillic acid, *p*-coumaric acid, ferulic acid and sinapic acid in rice bran extract had important roles in enzymatic browning inhibition of potato.

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Enzymatic browning is a major agricultural problem, especially in fresh-cut fruit and vegetables such as apples, bananas, grapes, potatoes, lettuce and other leafy vegetables (Busch, 1999). Browning is mainly caused by PPO activity, which is also known as catechol oxidase, catecholase, diphenol oxidase, *o*-diphenolase, phenolase and tyrosinase (Martinez and Whitaker, 1995). PPO is a copper-containing enzyme that catalyzes monophenols to *o*-diphenols through a hydroxylation reaction of monophenolase activity and *o*-diphenols to *o*-quinones through an oxidation reaction of diphenolase activity in the presence of oxygen (Saisung and Theerakulkait, 2011). These *o*-quinones are polymerized by themselves or interact with other compounds that produce dark pigments called melanins. Anti-browning agents such as ascorbic acid (Luo and Barbosa-Canovas, 1996; Bico et al., 2009), sodium chloride (Lu et al., 2007), citric acid (Almeida and Nogueira, 1995) and sulfites (Taylor et al., 1986) are used to control browning in fruit and vegetables. Sulfites are the most efficient browning inhibitors among these chemicals. However, they affect human health (McEvily et al., 1992; Zhu et al., 2007). Thus, consumers demand natural anti-browning agents to replace these synthetic compounds (Jang et al., 2002). Other researchers have reported on natural substances for enzymatic browning inhibition; for example, myricetin in pineapple peel extract (Saisung and Theerakulkait, 2011), 3',5'-di-C- β -glucopyranosylphloretin in calamondin peel extract (Lou et al., 2012), catechin, epicatechin, ellagic acid and gallic acid in pomegranate fruit peel extract (Fawole et al., 2012), gallic acid, ellagic acid and corilagin in longan fruit pericarp extract (Prasad et al., 2010), ellagic acid, gallic acid and tannic acid in mango seed kernel extract (Maisuthisakul and Gordon, 2009), gallic acid, procyanidin B2, (-)-galocatechin, (-)-epicatechin and (-)-epicatechin-3-gallate in litchi seeds extract (Nagendra et al., 2009), flavonoid-rich extract from Palo Fierro honey (De La Rosa et al., 2011) and protocatechuic acid, vanillic acid, *p*-coumaric acid, ferulic acid and sinapic acid in full-fatted and commercially defatted rice bran extracts (Sukhonthara et al., 2016). While these substances may be adequate to inhibit browning, there may be more effective alternatives and the availability of large quantities of mango peel may provide an economical alternative and this natural compound is safe for consumers. The mango varieties 'Chok-Anan', 'Nam-Dok-Mai' and 'Kaew' are well known for consumption and for use in industrial processing (Ledeker et al., 2014). If the peel waste from the food processing industry associated with these varieties of mango could be used as natural anti-browning agent, the industrial waste would be reduced and their would be added product value from the whole mangoes. Therefore, the objective of the current work was to investigate the effect of various varieties of mango peel extract on enzymatic browning inhibition of potato purée during storage.

Materials and Methods

Chemicals and reagents

Folin-Ciocalteu reagent was purchased from Merck (Darmstadt, Germany), triton X-100 was purchased from Fluka (Steinheim,

Germany) and sodium carbonate, polyvinylpyrrolidone, catechol and gallic acid were purchased from Sigma-Aldrich Co. (St. Louis, MO, USA).

Sample materials

Potato (*Solanum tuberosum* L.) bought from a local market in Bangkok, Thailand were used in this study. Ripe mango (cv. Chok-Anan) peel as the waste from the mango processing line was donated by The Peace Canning (1958) Co. Ltd., Chiang Mai, Thailand. Ripe mangoes (cv. Kaew and Nam-Dok-Mai) were purchased from a local market in Bangkok, Thailand and the peel from these samples was collected to use in this experiment.

Preparation of mango peel extract

These studies were performed on ripe peel samples of three different mango fruit (cv. Chok-Anan, cv. Kaew and Nam-Dok-Mai) which were extracted according to Sukhonthara and Theerakulkait (2012). Briefly, a sample was homogenized using distilled water (DW) at a ratio of ripe mango peel to DW of 1:6 (weight per volume) in a blender for 90 s. The sample was stirred using an overhead stirrer at 1,000 rpm at ambient temperature for 30 min and then the homogenate was centrifuged at 10,000 \times g at 25°C for 30 min. The supernatant was filtered through a cheese cloth, and then collected at 4°C after centrifuging; this was defined as mango peel extract (MPE). The concentration of each tested MPE sample was indicated as equal weight (in grams on a dry weight basis) of mango peel per milliliter of solvent (distilled water).

Effect of mango peel extract on browning inhibition in potato purée

Samples of potato were peeled and blended with the 'cv. Chok-Anan' mango peel extract (CMPE), 'cv. Kaew' mango peel extract (KMPE), 'Nam-Dok-Mai' mango peel extract (NMPE) or distilled water (DW), where DW was used as a control. The color values of the samples were measured using a colorimeter (Model RC-310; Minolta; New Jersey, USA) at 0 hr, 1 hr, 2 hr, 3 hr, 4 hr, 5 hr and 6 hr of storage at room temperature. The browning values $(\Delta L^*/L_0^*) \times 100$ were calculated; where ΔL^* is equal to $L_0^* - L^*$, L^* is the L^* value at any time and L_0^* is the initial L^* measurement. The percentage browning inhibition was calculated using Equation 1 according to Kubglomsong and Theerakulkait (2014):

$$\frac{(\text{Browning value}_{\text{control}} - \text{Browning value}_{\text{inhibitor}})}{\text{Browning value}_{\text{control}}} \times 100 \quad (1)$$

Effect of mango peel extract on potato polyphenol oxidase inhibition

Potato (100g) was blended for 20s with 100 mL of cold 0.1 M sodium phosphate buffer (pH 6.6) containing 0.5% Triton X-100 and 1% polyvinylpyrrolidone. The homogenate was centrifuged at 15,000 \times g at 4°C for 30 min (Galeazzi et al., 1981). The supernatant

was filtered through a cheese cloth and was collected at -20°C and was defined as crude enzyme.

MPE as the inhibitor was diluted at 1:10 (volume per volume) or DW (1 mL), 0.9 mL of 0.05 M sodium phosphate buffer at pH 6.6 and 1.0 mL of 0.2 M catechol (as the substrate) in 0.05 M sodium phosphate buffer at pH 6.6 were mixed and incubated for 30s. After that, 0.1 mL of crude enzyme was added and mixed gently. The absorbance was measured at 420 nm for 1 min using the spectrophotometer (using a method modified from Lee, 2002). One unit of enzyme activity was defined as the quantity of enzyme responsible for a change in absorbance of 0.001 at 420 nm in 1 min at 25°C and pH 6.6. The PPO activity in crude enzyme of each plant was converted to 588 unit/mL using 0.1 M sodium phosphate buffer at pH 6.6. The percent inhibition was calculated using Equation 2 according to Chaisakdanugull et al. (2007):

$$\frac{(\text{Activity of control} - \text{Activity of inhibitor})}{\text{Activity of control}} \times 100 \quad (2)$$

Determination of total phenolics content

The total phenolic compounds in the mango peel extracts were determined using Folin-Ciocalteu reagent with gallic acid as a standard phenolic compound. The method was modified from that described by Zou et al. (2011). Briefly, 50 μL of appropriately diluted sample or standard gallic acid solution was mixed with 1,950 μL distilled water and then 250 μL Folin-Ciocalteu reagent solution were added followed by 750 μL 7% Na_2CO_3 after 6 min and the solution subsequently was mixed gently. The reaction mixture was collected in the dark for 2 hr and the reaction was measured at 765 nm using a spectrophotometer (G-10; Thermo Fisher Scientific; Waltham, USA). The total phenolic compound was expressed as milligrams of gallic acid equivalents (mg GAE/100 g dry basis). All determinations were analyzed in triplicate.

Statistical analysis

Analyses of all experimental data were done in triplicate. Statistical significance was assessed using one-way analysis of variance using the SPSS software package (version 19; SPSS Inc.; Chicago, IL, USA). Significant differences among treatments were detected using Duncan's multiple range test at ($p \leq 0.05$).

Results and Discussion

Effect of mango peel extract on browning color in potato purée

Browning values of potato purée blended with mango peel extract and distilled water and stored at room temperature for up to 6 hr are shown in Fig. 1. The browning values of potato purée treated with MPE were lower than those treated with DW for all storage times ($p < 0.05$). The browning values of potato purée treated with CMPE were lower than those treated with NMPE or KMPE for 1–6 hr

($p < 0.05$). After storage for 2 hr, 4 hr, 5 hr and 6 hr, the browning values of potato purée treated with NMPE were lower than those treated with KMPE ($p < 0.05$). The browning values of potato purée treated with CMPE, NMPE, KMPE or DW after storage for 6 hr were 22.24, 25.69, 26.90 and 50.35, respectively (Fig. 1). The results indicated that CMPE could decrease the development of browning in potato purée occurring during storage more than the other varieties. The browning values of potato purée treated with CMPE, NMPE, KMPE or DW at different storage times were also analyzed (data not shown). The results showed that the browning values of potato purée treated with CMPE, NMPE, KMPE or DW at 6 hr storage were higher than those for the other storage times ($p < 0.05$); while the browning values of potato purée treated with NMPE at 3 hr and 4 hr or those treated with KMPE at 5 hr and 6 hr storage were not significantly different. Therefore, the final period of 6 hr storage was used for this study.

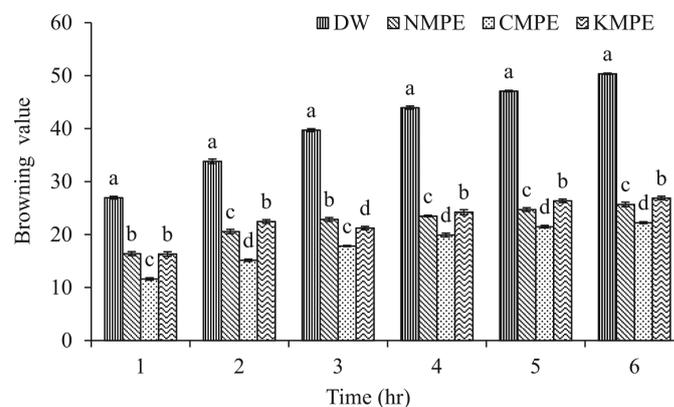


Fig. 1 Browning value ($(\Delta L^*/L_0^*) \times 100$) of potato purée treated with distilled water (DW), Nam-Dok-Mai mango peel extract (NMPE), cv. Chok-Anan mango peel extract (CMPE) or cv. Kaew mango peel extract (KMPE), where all samples were kept at ambient temperature for 6 hr and mean \pm SD with different letters above columns are significantly ($p < 0.05$) different for the same storage time

The decrease in the L^* value indicates a darker color, which is related to a higher browning color. The L^* values of potato purée treated with NMPE, CMPE or KMPE compared with DW are shown in Fig. 2. It was found that the L^* values of potato purée treated with CMPE were higher than those treated with KMPE, NMPE or DW during storage for 1–6 hr. The L^* values of potato purée treated with KMPE were higher than those treated with NMPE or DW during storage for 1–6 hr. The L^* values of potato purée treated with NMPE or KMPE were not significantly different during storage for 2 hr. After storage for 6 hr, the L^* values of potato purée treated with CMPE, KMPE, NMPE or DW were 57.85, 56.60, 56.00 and 37.77, respectively (Fig. 2). The results for the browning values and L^* values demonstrated that CMPE was more effective in browning inhibition of potato purée than NMPE or KMPE.

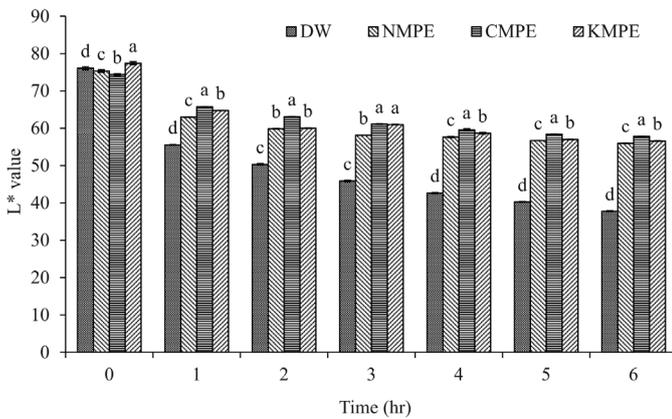


Fig. 2 L* values of potato purée treated with distilled water (DW), Nam-Dok-Mai mango peel extract (NMPE), cv. Chok-Anan mango peel extract (CMPE) or cv. Kaew mango peel extract (KMPE), where all samples were kept at ambient temperature for 6 hr and mean \pm SD with different letters above columns are significantly ($p < 0.05$) different for the same storage time.

A change in the color from yellow to red shows a decrease in the hue angle and this indicates browning color formation (Nicoli et al., 1994). The hue angles of potato purée treated with mango peel extracts compared to DW are shown in Fig. 3. The hue angles of potato purée treated with mango peel extracts were higher (decreased less) than those treated with DW after storage for 1–6 hr ($p < 0.05$) and the hue angles of potato purée treated with CMPE were higher than those treated with NMPE, KMPE or DW at storage times of 2–3 hr. The hue angles of potato purée treated with CMPE, NMPE or KMPE were not significantly different after storage for 5–6 hr. These results indicated that there was little change in the color from yellow to red in these samples at 5–6 hr. The hue angles of potato purée treated with CMPE, NMPE, KMPE or DW at 6 hr storage had values of 87.67, 87.07, 86.30 and 65.50, respectively.

The percentages of browning inhibition of potato purée treated with CMPE were higher than those treated with KMPE or NMPE for all storage times ($p \leq 0.05$; Table 1). The percentages of browning inhibition of potato purée treated with NMPE or KMPE were not significantly different after storage for 1–4 hr. The percentages of browning inhibition in potato purée treated with CMPE, NMPE or KMPE at 6 hr storage were 55.82%, 48.97% and 46.58%, respectively. These results demonstrated that CMPE was more effective in browning inhibition of potato purée than NMPE or KMPE. CMPE

might have contained phenolic compounds that could inhibit the PPO isozyme in potato and each phenolic compound might have had different specific inhibition activity on different PPO isozymes. Flurkey (1986) also reported that there are different isozymes of the PPO enzyme in each type of plant. Gallic acid, protocatechuic acid and gentisic acid were the prominent phenolic compounds in the peel of different mangoes and these compounds have a structure similar to the substrate and might inhibit browning (Ajila et al., 2010).

Effect of mango peel extract on polyphenol oxidase inhibition

The percentage inhibition of potato PPO activity by the different varieties of mango peel extracts are shown in Fig. 4. CMPE inhibited potato PPO activity more than NMPE or KMPE with percentage inhibition values of 47.16, 38.32 and 34.95 respectively ($p \leq 0.05$). The percentage of PPO inhibition of CMPE was also compared with a commercial anti-browning agent (20 parts per million of citric acid and sodium metabisulfite) and the result showed that CMPE had a higher inhibitory effect on potato PPO than citric acid by about 6-fold but this was lower than for sodium metabisulfite by about 2-fold (data not shown). The results confirmed that CMPE had greater inhibition of potato PPO than did NMPE or KMPE.

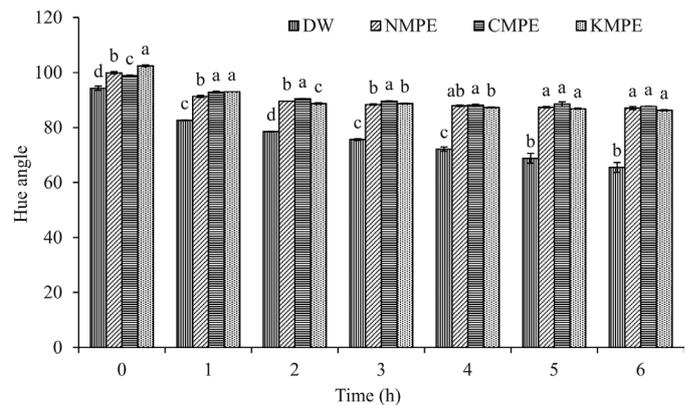


Fig. 3 Hue angle of potato purée treated with distilled water (DW), Nam-Dok-Mai mango peel extract (NMPE), cv. Chok-Anan mango peel extract (CMPE) or cv. Kaew mango peel extract (KMPE), where all samples were kept at ambient temperature for 6 hr and mean \pm SD with different letters above columns are significantly ($p < 0.05$) different for the same storage time

Table 1 Percentage browning inhibition in potato purée samples treated with Nam-Dok-Mai mango peel extract (NMPE), cv. Chok-Anan mango peel extract (CMPE) or cv. Kaew mango peel extract (KMPE), where all samples were kept at ambient temperature for 6 hr

Mango peel extract	Percentage browning inhibition at storage time					
	1 hr	2 hr	3 hr	4 hr	5 hr	6 hr
NMPE	39.20 \pm 0.81 ^b	39.19 \pm 0.55 ^b	42.42 \pm 0.71 ^c	46.53 \pm 0.38 ^b	47.50 \pm 0.61 ^b	48.97 \pm 0.74 ^b
CMPE	56.89 \pm 0.69 ^a	55.20 \pm 0.41 ^a	55.07 \pm 0.01 ^a	54.68 \pm 0.57 ^a	54.34 \pm 0.53 ^a	55.82 \pm 0.39 ^a
KMPE	39.43 \pm 1.64 ^b	33.61 \pm 0.66 ^c	46.54 \pm 0.48 ^b	44.86 \pm 1.45 ^b	43.98 \pm 0.75 ^c	46.58 \pm 0.69 ^c

Note: mean \pm SD with different lowercase superscripts in the same column are significantly ($p < 0.05$) different

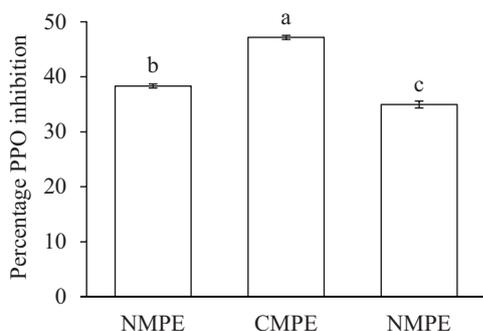


Fig. 4 Percentage potato polyphenol oxidase (PPO) activity inhibition by Nam-Dok-Mai mango peel extract (NMPE), cv. Chok-Anan mango peel extract (CMPE) or cv. Kaew mango peel extract (KMPE), where mean \pm SD with different letters above columns are significantly ($p < 0.05$) different

The total phenolic content of Nam-Dok-Mai mango peel extract (NMPE), cv. Chok-Anan mango peel extract (CMPE) and cv. Kaew mango peel extract (KMPE) are shown in Fig. 5. The total phenolic content of CMPE was at a similar extent as NMPE ($p > 0.05$), but higher than KMPE ($p < 0.05$). The total phenolic contents of the extracts from CMPE, NMPE or KMPE were 2,221 mg GAE per 100 g dry basis, 146 mg GAE per 100 g dry basis and 1,450 mg GAE per 100 g dry basis. CMPE had more effective enzymatic browning inhibition than KMPE. This might have been due to the high amounts of active phenolic compounds of CMPE that could inhibit enzymatic browning. The content of phenolic compounds depends on the variety and tissue of the plant (Rangkadilok et al., 2007). The total phenolic content in ripe mango peel extracts has been reported to be higher than for the raw mango peel extracts (Ajila et al., 2007). The structure of the phenolic compounds in CMPE might be similar to the substrate and so act as a competitive inhibitor of PPO. The competitive inhibitor could bind with the active site of the enzyme and prevent the binding of substrate molecule, which could lead to lower PPO activity. The total phenolic contents in mango peel have been reported in the range 2,032–3,185 mg GAE/100 g dry basis (Sogi et al., 2013). Ajila and Prasada Rao (2013) found that the total

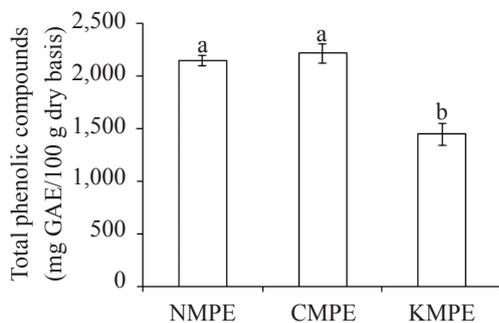


Fig. 5 Total phenolic compounds of Nam-Dok-Mai mango peel extract (NMPE), cv. Chok-Anan mango peel extract (CMPE) or cv. Kaew mango peel extract (KMPE), where mean \pm SD with different letters above columns are significantly ($p < 0.05$) different and GAE = gallic acid equivalents

phenolic contents in the Raspuri and Badami varieties of mango peel extracts were in the range 810–2,950 mg GAE/100 g dry basis. Masibo and He (2008) reported that the phenolic compounds in the mango peel consisted of mangiferin, quercetin, rhamnetin, ellagic acid, kaempferol. Sukhonthara et al. (2016) reported that ferulic, protocatechuic acid, vanillic acid, *p*-coumaric acid and sinapic acid (all phenolic compounds in rice bran extract) played a role in the enzymatic browning inhibition in potato purée.

The Chok-Anan mango peel extract (CMPE) had higher percentages of enzymatic browning inhibition in potato purée and inhibition of potato PPO activity than NMPE or KMPE. Therefore, CMPE could be prepared as an anti-browning agent which could add value to the mango peel that otherwise would be a waste by-product in the mango processing industry.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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