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Effect of guar gum and glycerol on oil absorption and qualities of banana chips

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Abstract

The application of hydrocolloid as an edible coating can reduce oil absorption in fried products, leading to foods with lower oil content for consumers who are concerned about their health. The main purpose of the present work was to investigate the effect of guar gum and glycerol coating on oil absorption, physical properties, and sensory acceptance of fried banana chips. The results revealed that guar gum (1.00% w/w) and glycerol (5.66% w/w) coating provided the lowest oil content of fried banana chips (with 33.02% oil reduction as compared to the uncoated sample, and 15.19% oil reduction as compared to the sample coated with guar gum alone); highest fracturability and hardness with a slight change in colour, and acceptable sensory characteristics.

Introduction

Fried banana chips are produced by deep-frying thin slices of under-ripe mature bananas (Azam-Ali, 2008), and widely consumed in Southeast Asia (Suyatma *et al.,* 2015). Indeed, bananas are the fourth world largest fruit crop produced in both small and large scales (Potato Chips Machinery, 2014), worth approximately $35.5 million in 2005, with an annual increase of 10 - 15% forecasted growth in the international market (DCED, 2012).

Frying is a food processing method, which causes changes in the physical and chemical properties, such as denaturation of protein, starch gelatinisation, crust formation, and water vaporisation (Rimac-Brnčić *et al.,* 2004). The heat and mass transfer during frying leads to water movement from the product and oil movement into the product (Singthong and Thongkaew, 2009). Thus, fried products have a very high-fat content, accounting for 50% of the total weight of the fried product (Pinthus *et al.,* 1993; Bouchon, 2009). The consumption of high-fat products can lead to hypertension, hypercholesterolemia (Albert and Mittal, 2002), coronary heart disease, and obesity (Sothornvit, 2011). Therefore, there have been attempts to decrease oil uptake in fried foods, especially pre-treating the raw material before frying, such as blanching, osmotic dehydration, microwave or convection drying, and the application of edible coatings (Martínez *et al.,* 2015). Several types of food hydrocolloids as edible coatings have been investigated to reduce oil absorption in fried products since they are a good barrier to lipids, oxygen, and carbon dioxide during frying (Albert and Mittal, 2002). Guar gum (2.00% based on chickpea flour) could reduce the oil content of fried chickpea products by 30 - 33% (Annapure *et al.,* 1999). Moreover, Martínez *et al.* (2015) recently reported that an edible coating of 1.2% guar gum for 30 s before frying could reduce the oil content of fried plantain snacks by 43%. In addition, Yu *et al.* (2016) reported that edible coating of fried potato chips with guar gum (1% w/w) and glycerol (8% w/w) could reduce oil absorption by 34.8%.

In edible coatings of food hydrocolloids, a plasticiser with low molecular weight can be used to improve the mechanical properties of the coating, including flexibility and adhesion. It can also be used to eliminate cracks and pores in the product (Donhowe and Fennema, 1993). One such plasticiser is glycerol (E 422), generally used in polysaccharide-based edible coating (Garcia *et al.,* 2011), which has been authorised as a food additive in the EU (Mortensen *et al.,* 2017). Since glycerol can be naturally found in fats and other foods, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) also approved the application of glycerol with 'not specified' acceptable daily intake (ADI).

The present work thus aimed to investigate the effect of a coating of guar gum and glycerol on oil absorption, physical properties, and sensory acceptance of fried banana chips.

Materials and methods

Materials

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Bananas (*Musa sapientum* L.) at maturity stage 1 (Madan *et al.,* 2014) were purchased from the local market of Nonthaburi, Thailand. $CaCl_2$ (food-grade) was purchased from Qingdao Huadong Calcium Producing Co. Ltd., China. Guar gum and glycerol (food-grade) were purchased from Chemipan Corporation Co. Ltd., Thailand.

Sample preparation

The bananas were thoroughly washed with tap water, peeled and manually cut into slices of 2.0 ± 0.5 mm in thickness, and 25 ± 3 mm in diameter. The banana slices were immersed in 0.5% (w/v) $CaCl_2$ solution for 1 min, and drained for 5 min to slow down enzymatic browning (Danyen *et al.,* 2009). The samples were then immersed in 0.50, 0.75, or 1.00% (w/w) guar gum for 3 min, and drained for 20 min before placing in the hot air oven (Memmert D-91126, Germany) at 100°C for 4, 6, or 7 min, respectively, to obtain a moisture content of 65 ± 5%. Uncoated (control, no coating, or drying applied) and coated samples were fried in a preheated thermostatically temperature-controlled fryer (Fritel International FRI-4355, Belgium) filled with 3 L of palm oil (Oleen Co. Ltd., Thailand) at 175 ± 2°C for 2 min and 30 s. The ratio of banana weight to oil volume was 1:30. After frying, all fried banana chips were drained and cooled to room temperature for 5 min before the analysis of oil content, texture, and colour. Fresh oil was used for different batches of samples.

The appropriate concentration of guar gum for the lowest oil content with suitable texture and colour of banana chips was selected for the study of the effect of guar gum and glycerol on banana chips. The procedures of sample preparation were the same as described earlier, except that the coating solution contained guar gum (at the appropriate concentration) and glycerol (1.96, 3.85, or 5.66% w/w). Then, the oil content, texture, and colour of the samples were analysed.

Determination of oil content

The oil content of fried banana chips was determined using solvent extraction by Soxhlet (AOAC, 2012).

Determination of moisture content

The moisture content of the samples was determined following (AACC, 2002) and Mulla *et al.* (2017) with slight modification. Ground samples (2 g) were dried at 105°C in a hot air oven for at least 2 h until a constant weight was obtained.

Texture analysis

The fracturability and hardness of the samples were determined using a texture analyser TA.XT2i (Stable Micro Systems Ltd., UK). A force using a spherical stainless probe (P/0.25S) of 2 mm diameter was applied on the sample placed on the HDP/CFS (Crisp Fracture Support Rig and corresponding platform, SMS). The test settings were pre-test speed of 1.00 mm/s, test speed of 2.00 mm/s, travel distance of the probe set at 5.0 mm, post-test speed of 10.00 mm/s, and trigger force of 20.0 g. The first peak of the force and the maximum force at compression from the force-deformation curves were determined as the fracturability and hardness of fried banana chips, respectively (Lujan-Acosta and Moreira, 1997; Jiang *et al.,* 2019).

Determination of colour

The colour of the samples was determined using the CIELAB colour parameters, L*, C*, and h* by Hunter colorimeter (Colour Quest 45/0, Hunter Associates Laboratory Inc., Reston, VA, USA). Standard white and black reflector plates were used for calibration. D65 was used as a light source with a standard observer at 10° and a 50 mm diameter measuring area. Four quadrant positions per each sample were measured.

Sensory acceptance

The selected samples with the lowest oil content with appropriate texture and colour were evaluated for sensory acceptability based on crispiness, colour, taste, and overall acceptance as compared to the control sample by 30 untrained panellists screened from juniors and seniors in the Faculty of Applied Science, King Mongkut's University of Technology North Bangkok, Thailand. The sensory attributes were rated using a nine-point hedonic scale, where 9 represented like extremely, and 1 represented dislike extremely. All samples were randomly labelled with a 3-digit number for identification and presented in random order.

Statistical analysis

All experiments were conducted in triplicate, and data were analysed by analysis of variance (ANOVA) with Duncan's multiple range test (DMRT) for determining significant differences among means using IBM SPSS Statistics 21 (IBM Corporation, Armonk, USA) The level of significance was defined as $p < 0.05$.

Results and discussion

Effect of guar gum on oil content and physical properties of banana chips

Table 1. Oil content and texture of banana chips coated with different concentrations of guar gum.

Concentration of guar gum (% w/w)	Oil content (%)	Moisture content (%)	Texture	
			Fracturability (g)	Hardness (g)
0	43.25 ± 1.29[a]	1.66 ± 0.03[b]	175.03 ± 11.48[b]	177.26 ± 10.89[c]
0.50	39.51 ± 0.57[b]	1.84 ± 0.24[b]	183.73 ± 6.53[b]	192.39 ± 4.79[c]
0.75	37.01 ± 1.70[c]	2.18 ± 0.11[a]	224.49 ± 5.59[a]	247.97 ± 17.35[b]
1.00	34.09 ± 1.02[d]	2.36 ± 0.24[a]	236.73 ± 24.55[a]	269.90 ± 7.02[a]

Different superscripts within the same column indicate significant difference between samples by Duncan multiple range test ($p < 0.05$).

Table 1 presents the oil content, moisture content, fracturability, and hardness of banana chips coated with different concentrations of guar gum. As concentrations of guar gum increased, the oil content of samples significantly decreased ($p < 0.05$); while the moisture content, fracturability and hardness increased. The sample with the lowest oil content was the banana chips coated with 1% guar gum. The surface of the coated product became more brittle and stronger with fewer cracks, resulting in less evaporation and oil uptake, while trapping moisture inside the product thus reducing water replacement with oil. Moreover, $CaCl_2$ can cross-link with hydrocolloids and provide a fine network on the product surface, leading to less oil migration into the food product during frying (Singthong and Thongkaew, 2009). Martínez *et al.* (2015) also found the reduction of oil content of deep-fried plantain slices by 43, 31, and 23% with the application of edible coating with guar gum, carboxymethyl cellulose (CMC), and xanthan gum, respectively, as well as a significant increase of moisture content when a higher concentration of guar gum was applied. Singthong and Thongkaew (2009) reported the effectiveness of a cross-linked network of hydrocolloids (alginate, CMC, and pectin) and $CaCl_2$ on oil absorption in fried banana chips. Garmakhany *et al.* (2008) observed the reduction of oil absorption in potato chips by 54.7% when coated with 0.3% guar gum. Moreover, the reduction of oil uptake by 41% of French fries coated with 0.9% guar gum has been reported by Kim *et al.* (2011).

Hardness and fracturability are important physical quality parameters of fried products. In the present work, hardness and fracturability were defined as the maximum force and the first peak of the force at compression from the force-deformation curves, respectively (Lujan-Acosta and Moreira, 1997; Jiang *et al.,* 2019). Fracturability is the textural property of a product to fracture, crack or crumble when a small amount of force is applied. It is usually found in baked products and dry snacks with high hardness and low cohesiveness (Stable Micro Systems, 2020). The higher fracturability and hardness in coated samples as compared to the uncoated sample could occur due to the cross-linked network between guar gum and $CaCl_2$, which increases the strength of cell wall and middle lamella of the bananas, resulting in the protection of the food surface during frying (Khalil, 1999). Singthong and Thongkaew (2009) also found an increase of hardness in fried banana chips coated with hydrocolloids (alginate, CMC, and pectin) cross-linked with $CaCl_2$. Moreover, banana fritters coated with 1% carrageenan or 1% xanthan gum were harder as compared to the control as reported by Norizzah *et al.* (2016).

The colour parameters (L*, C*, and hue angle) of banana chips coated with different concentrations of guar gum are presented in Table 2. The lightness of samples increased while C* decreased as guar gum concentration in the coating increased. Therefore, the coated products were lighter in colour as compared to the uncoated sample. However, there was no significant difference in the hue angle among samples ($p \geq 0.05$). During frying, a colour change due to Maillard reaction in the reducing sugars and amino acids can occur in the product at high temperatures. The cross-linked coating may protect some reducing terminals from amino acids of the product and decelerate the browning reaction (Hua *et al.,* 2015). Singthong

Table 2. Colour of banana chips coated with different concentrations of guar gum.

Concentration of guar gum (% w/w)	L*	C*	Hue angle^{ns} (°)
0	67.01 ± 2.02^{b}	33.18 ± 2.68^{a}	82.42 ± 2.03
0.50	67.80 ± 2.14^{b}	31.85 ± 1.64^{ab}	82.93 ± 0.54
0.75	71.38 ± 1.95^{a}	28.80 ± 1.39^{b}	84.58 ± 0.68
1.00	72.24 ± 0.97^{a}	28.97 ± 2.01^{b}	84.66 ± 0.59

Different superscripts within the same column indicate significant difference between samples by Duncan multiple range test ($p < 0.05$); ^{ns}no significant difference between samples ($p \geq 0.05$).

Table 3. Oil content and texture of banana chips coated with different concentrations of guar gum and glycerol.

Concentration of guar gum (% w/w)	Concentration of glycerol (% w/w)	Oil content (%)	Moisture content (%)	Texture	
				Fracturability (g)	Hardness (g)
0	0	43.25 ± 1.29^{a}	1.66 ± 0.03^{c}	175.03 ± 11.48^{d}	177.26 ± 10.89^{e}
1.00	0	34.09 ± 1.02^{b}	2.36 ± 0.24^{b}	236.73 ± 24.55^{c}	269.90 ± 7.02^{d}
1.00	1.96	32.47 ± 0.30^{c}	2.44 ± 0.14^{b}	281.13 ± 13.23^{b}	345.65 ± 24.53^{c}
1.00	3.85	31.40 ± 0.53^{c}	2.58 ± 0.23^{b}	363.98 ± 0.06^{a}	391.08 ± 1.20^{b}
1.00	5.66	28.97 ± 0.36^{d}	3.12 ± 0.27^{a}	366.20 ± 12.83^{a}	441.49 ± 47.89^{a}

Different superscripts within the same column indicate significant difference between samples by Duncan multiple range test ($p < 0.05$).

and Thongkaew (2009) also reported that fried banana chips coated with alginate were lighter as compared to the control sample ($p \leq 0.05$), but there was no significant difference in redness (a*) between uncoated and alginate-coated samples ($p > 0.05$). Hua *et al.* (2015) observed a weak browning reaction and slight colour change in potato chips coated with low-methoxyl sunflower head pectin cross-linked with $CaCl_2$.

Since banana chips coated with 1.00% guar gum had the lowest oil content (with 21.18% oil reduction as compared to the uncoated sample), as well as the highest fracturability and hardness with a slight change in colour, this guar gum concentration was selected to investigate the effect of guar gum and glycerol on fried banana chips.

Effect of guar gum and glycerol on the oil content and physical properties of banana chips

Table 3 presents the oil content, moisture content, fracturability, and hardness of banana chips coated with guar gum and glycerol. As concentrations of glycerol increased, the oil content of samples decreased while moisture content, fracturability, and hardness increased significantly ($p < 0.05$). The sample with the lowest oil content was the sample coated with 1% guar gum and 5.66% glycerol. Glycerol is hydrophilic; thus, it can increase the water holding capacity and barrier properties, as well as the mechanical properties of the edible coating (Ghasemlou *et al.,* 2011; Cerqueira *et al.,* 2012). Moreover, glycerol can decrease gaps between cells or cracks on the surface of the products, resulting in less water evaporation and oil absorption (Patsioura *et al.,* 2015; Yu *et al.,* 2016). Yu *et al.* (2016) reported that guar gum and glycerol could significantly decrease the oil content of fried potato chips as compared to the control and the sample coated with guar gum alone ($p \leq 0.05$).

The higher fracturability and hardness of coated samples might be due to the adhesiveness of guar gum and glycerol, as well as the ability of glycerol to reduce cracks on the product surface (Patsioura *et al.,* 2015; Yu *et al.,* 2016). Therefore, more force is required to break the products. Similar results were

Table 4. Colour of banana chips coated with different concentrations of guar gum and glycerol.

Concentration of guar gum (% w/w)	Concentration of glycerol (% w/w)	L*	C*	Hue angle (°)
0	0	67.01 ± 2.02^{b}	33.18 ± 2.68^{a}	82.42 ± 2.03^{b}
1.00	0	72.24 ± 0.97^{a}	28.97 ± 2.01^{b}	84.66 ± 0.59^{a}
1.00	1.96	66.18 ± 0.65^{b}	31.70 ± 1.77^{ab}	80.82 ± 1.02^{bc}
1.00	3.85	63.78 ± 0.27^{c}	31.04 ± 0.51^{ab}	79.20 ± 0.73^{cd}
1.00	5.66	63.15 ± 0.92^{c}	32.07 ± 0.07^{ab}	78.09 ± 0.77^{d}

Different superscripts within the same column indicate significant difference between samples by Duncan multiple range test ($p < 0.05$).

Table 5. Sensory acceptance of banana chips coated with different concentrations of guar gum and glycerol.

Concentration of guar gum (% w/w)	Concentration of glycerol (% w/w)	Crispiness	Colour	Taste	Overall acceptance
0	0	6.63 ± 1.16^{a}	6.83 ± 1.49^{a}	6.90 ± 1.24^{a}	7.07 ± 1.08^{a}
1.00	0	4.93 ± 2.00^{b}	6.37 ± 1.85^{a}	5.57 ± 1.59^{b}	5.83 ± 1.46^{b}
1.00	5.66	6.27 ± 1.98^{a}	5.40 ± 1.75^{b}	5.50 ± 1.50^{b}	6.03 ± 1.54^{b}

Different superscripts within the same column indicate significant difference between samples by Duncan multiple range test ($p < 0.05$).

observed by Yu *et al.* (2016) in fried potato chips coated with guar gum and glycerol, as well as Suárez *et al.* (2008) in dough coated with methylcellulose and sorbitol. However, Jia *et al.* (2017) and Tavera-Quiroz *et al.* (2012) did not find any significant difference in hardness when using sorbitol as a plasticiser in guar gum coating on French fries and methylcellulose coating on potato chips, respectively.

The colour parameters (L*, C*, and hue angle) of banana chips coated with different concentrations of guar gum are presented in Table 4. The lightness and hue angle of samples decreased, while C* of samples was not significantly different. However, Jia *et al.* (2017) and Tavera-Quiroz *et al.* (2012) did not find any significant changes in colour when using sorbitol as a plasticiser in guar gum coating on French fries and methylcellulose coating on potato chips, respectively.

Since banana chips coated with 1.00% guar gum and 5.66% glycerol had the lowest oil content (with 33.02% oil reduction as compared to the uncoated sample, and 15.19% oil reduction as compared to the coated sample without glycerol), as well as the highest fracturability and hardness with a slight change in colour, this formulation was selected to study the sensory acceptance.

Sensory acceptance

The sensory acceptance results of control and samples coated with guar gum and glycerol are shown in Table 5. The sample coated with guar gum and glycerol was not significantly different to control in crispiness ($p \geq 0.05$), while the sample coated with guar gum was not significantly different with control in colour ($p \geq 0.05$), suggesting that the panellists might not notice the different appearance and texture between uncoated and coated samples. However, the control sample had the highest sensory scores in taste and overall acceptance, indicating that the consumers preferred the traditional fried banana chips to the coated chips. This may be due to the coated products containing less oil but more moisture which could directly affect the mouthfeel, as well as lower the lipid-soluble flavour compounds in the banana chips (Hua *et al.,* 2015). Similar results were found for the coating of low-methoxyl sunflower head pectin on fried potato chips (Hua et al., 2015). In the previous research of banana fritters, samples coated with carrageenan or xanthan gum also obtained a lower acceptance score in colour than the control; nevertheless, there was no significant difference in crispiness, oiliness, taste, and overall acceptance (Norizzah et al., 2016).

Conclusion

Guar gum and glycerol coating on banana chips of 1.00 and 5.66%, respectively, provided the lowest oil content of the banana slices (33.02% oil reduction as compared to the uncoated sample, and 15.19% oil reduction as compared to the sample coated with guar gum alone), as well as the highest fracturability and hardness with a slight change in colour and acceptable sensory characteristics.

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