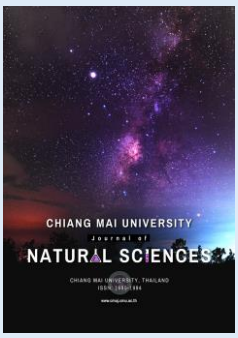

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Research article

Effect of Sacha Inchi Pressed-Cake (*Plukenetia volubilis* L.) on the Physical, Chemical and Sensory Properties of Tuiles

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Abstract The objective of this research was to study the effect of sacha inchi pressed-cake (SPC) on the physical, chemical and sensory properties of tuiles. The addition of SPC in tuiles can increase the nutritive value in terms of protein and antioxidant efficiency. The ratios of SPC to wheat flour varied from 50:50, 60:40 and 70:30 by weight. The color, textural properties and antioxidant activities of tuiles were determined. The sensory evaluation was conducted by 30 elderly with age between 60 to 70 years. Results showed that the moisture, protein and fat contents of the tuiles with sacha inchi pressed-cake (TSPC) significantly increased with increasing level of SPC. The color values (L*and b*) of tuiles also significantly decreased ($P \leq 0.05$), while a* value significantly increased ($P \leq 0.05$) when increasing SPC content. The textural properties showed that increased level of SPC resulted in increase of hardness and crispness of TSPC ($P \leq 0.05$). Tuile with 50% SPC showed the highest sensory quality attributes of liking and JAR. In conclusion, the total phenolic content and antioxidant activities by DPPH, FRAP and ORAC assay of TSPC at the ratio of SPC to wheat flour of 50:50 were higher than tuile without SPC.

Keywords: Elderly, Pressed Cake, Sacha Inchi, Substituting, Tuiles

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INTRODUCTION

Currently, the elderly population at age 65 growing the fastest. In all, 703 million persons aged 65 years or over were currently in the world in 2019 (United Nations, 2019). That proportion is projected to rise further to 16% by 2050, so that one in six people in the world will be aged 65 years or over (United Nations, 2019). In 2018, the number of Thai elderly was 12 million of the total of 66 million, or approximately 18% of the total population (Prasartkul, 2018). Physiological changes occur with aging in all organ systems such as blood pressure and glucose levels increase, and the gastrointestinal system develops disorders. Protein-energy malnutrition is a major problem in older subjects. It is hypothesized that inadequate dietary protein may be associated with physical frailty (Schoufour et al., 2019). In addition the loss of muscle mass, mastication and nutritional problems are common among the elderly (Boss and Seegmiller, 1981). The elderly have been identified as a population group at high risk of poor nutrition, low sensory perception of foods, and reduced thirst, resulting in deficiencies in energy and nutrient intake, especially micronutrients and protein (Gil-Montoya et al., 2015).

Sacha inchi (*Plukenetia volubilis* L.), also known as Inca inchi or Inca peanut, is a plant of the Euphorbiaceae family. This plant, widely cultivated in Peru, has long been a staple in the diet of various native tribal groups there. Currently, the plant is also widely cultivated in the northern part of Thailand (Rawdkuen et al., 2016). The chemical characterization has shown that the seeds have high protein (33%) and oil (49%) contents (Liu et al., 2014). Sacha inchi is considered a rich source of pharmaceutical components to prevent and treat diseases and ailments (Quinteros et al., 2016). Sacha inchi pressed-cake (SPC) is a by-product of traditional oil processing. The obtained by-product still contains various amounts of nutritional value such as insoluble dietary fibers and protein content (Chirinos et al., 2013). SPC is a good source of protein and has health promoting effects. The addition of various proportions of SPC in tuiles can increase the nutritive value in terms of protein.

Tuiles are a type of cookie in France. Tuiles are very thin and delicate containing wheat flour, sugar and butter as the main ingredients. Tuiles are ideal for nutrient availability, palatability, compactness, and convenience (Sharif et al., 2009). The addition of functional ingredients to bakery products has risen in popularity due to the ability to reduce the risk of chronic diseases beyond basic nutritional functions (Martins et al., 2017). Tuiles can be used as a source of essential fatty acid supplementation and protein by adding SPC. Therefore, the objective of this research was to study the effect of SPC on physical, chemical and sensory properties of tuiles.

MATERIALS AND METHODS

Materials

SPC was obtained from Nikao Corporation Co., Ltd. in Rayong, Thailand. SPC was milled by grinder machine (JSP-500, China), boiled for 20 min for removing of off-flavor, dried in a hot air oven at 70°C for 12 hr, and then cooled down to room temperature. The SPC was passed through a sieve with particle size of 120 mesh, packed in polyethylene laminated with an aluminum foil bag, vacuum-sealed and stored at -20°C before analysis.

Chemical compositions of sacha inchi pressed-cake (SPC) and tuiles with sacha inchi pressed-cake (TSPC)

The moisture, protein, fat, ash, and crude fiber contents of SPC were analyzed according to AOAC (2012). The carbohydrate content of SPC was calculated by difference (100 - %moisture - %protein - %fat - %ash - %crude fiber).

Preparation of tuiles with sacha inchi pressed-cake (TSPC)

The effect of SPC contents on tuiles qualities was studied. The tuiles were prepared by substituting wheat flour with SPC at 0, 50, 60 and 70% by weight.

The physical, chemical and sensory properties of TSPC were evaluated, and the color values (L*, a*, b*) of tuiles were measured in CIE system using a spectrophotometer (ColorFlex EZ, Hunter Associates Laboratory Inc., Virginia, USA. Hardness and crispness of 10 pieces of tuiles were evaluated by Texture Analyzer (Lloyd Instruments TA1). Hardness and crispness of tuiles were evaluated by measuring the peak of breaking force (N) using a crisp fracture jig.

Sensory properties of tuiles with sacha inchi pressed-cake (TSPC)

The sensory properties of TSPC were evaluated by 30 semi-trained elderly panelists; 15 men, 15 women, aged 60 to 70 years. Each samples was labeled with three random numbers. The sample were evaluated for the following attributes: hedonic scale for appearance, color, odor, taste, crispness, hardness and overall (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). The color, crispness and sweetness were evaluated using a 5-point just-about-right scale: color JAR: 1 = much too light, 2 = too soft, 3 = just about right, 4 = too dark, 5 = much too dark ; crispness JAR: 1 = much too soft, 2= too soft, 3 = just about right, 4 = too crisp, 5 = much too crisp ; sweetness JAR: 1 = much too little, 2 = too little, 3 = just about right, 4 = too sweet, 5 = much too sweet.

Determination of total phenolic content and antioxidant activities of sacha inchi pressed-cake (SPC), tuile without sacha inchi pressed-cake (TWSPC) and tuile with 50% sacha inchi pressed-cake

Sample extraction. The SPC, TWSPC and TSPC with 50% SPC were determined total phenolic contents (TPC) and antioxidant activities. They were extracted with 20% ethanol with a solvent to the sample ratio of 1:10 using a shaking water bath at 70°C for 30 min. The mixture was centrifuged for 15 min at 25°C and filtered through Whatman No.1 filter paper. The supernatant was kept in brown glass bottles and stored at -20°C until further analysis.

Determination of total phenolic content (TPC)

Total phenolic content was determined using the Folin-Ciocalteu method as modified by Amarowicz et al. (2004). The extracts (25 µl) were reacted with 10% (v/v) Folin-Ciocalteu reagent (50 µl). After adding 7.5% (w/v) sodium bicarbonate (200 µl) and incubated in dark room at 25 ± 5°C for 2 hrs. The absorbance of the resulting solution was measured at 765 nm. Gallic acid solutions (10, 20, 40, 60, 80, 100 and 200 µg/ml) were used as a standard, and deionized water was used as a blank. Total phenolic content was expressed as milligrams of gallic acid equivalents per 100 g of dry weight of sample. This experiments were carried out in triplicate. The absorbance was measured at 765 nm using a microplate reader.

Determination of antioxidant activities

2, 2-Diphenyl-1-picrylhydrazyl radical scavenging activity (DPPH assay). DPPH assay was determined following a modified method of Fukumoto and Mazza (2000). The extracts (22 µl) were reacted with 200 µl DPPH (150 µM) solution and incubated in dark room at 25 ± 5 °C for 30 min. The absorbance of the resulting solution was measured at 520 nm. Trolox solutions (0.01, 0.02, 0.04, 0.08, 0.16, 0.32 and 0.64 mM) were used as a standard, and 95% ethanol solution (v/v) was used as a blank. The DPPH radical scavenging activity was expressed as µmole Trolox equivalents per 100 g of dry weight of sample. The absorbance was determined at 520 nm using a microplate reader.

Ferric reducing antioxidant power (FRAP) assay. The FRAP assay was determined according to the modified method of Benzie and Strainin (1996). The extracts (20 µl) were reacted with FRAP reagent (150 µl) and incubated in dark room

at 25 ± 5°C for 8 min. The absorbance of the resulting solution was measured at 600 nm. Trolox solution (6.25, 12.5, 25, 50, 100, 200 and 400 µM) was used as a standard, and deionized water was used as a blank. The FRAP values were expressed as µmole Trolox equivalents per 100 g of dry weight of sample. The absorbance of the resulting solution was measured at 600 nm.

Oxygen radical absorbance capacity (ORAC) assay. The ORAC assay was determined according to the method as explained by Ou et al. (2001). The fluorescence intensity was monitored for 90 min using a microplate, with an excitation wavelength of 485 nm and emission wavelength of 528 nm.

Statistical analysis

Mean values, standard deviation, and analysis of variance (ANOVA) were computed using a commercial statistical package SPSS 18.0 (SPSS Inc., Chicago, IL, USA). These data were then compared using Duncan's multiple range tests at 95% significance level.

RESULTS

Chemical compositions of sacha inchi pressed-cake (SPC)

Protein content (57.34%) was major composition in SPC, also content of moisture, fat, ash, crude fiber and carbohydrate of SPC were 7.49, 20.15, 5.27, 7.58 and 2.17%, respectively (Table 1). The moisture content of SPC was within the range of 0-13% reported to be suitable for storage and processing without microorganism degradation of the triacylglycerols (Gutierrez et al., 2011).

Table 1. Chemical compositions of sacha inchi pressed-cake (SPC).

Composition	(%)
Moisture	7.49 ± 0.03
Ash	5.27 ± 0.08
Protein	57.34 ± 0.67
Fat	20.15 ± 0.63
Crude fiber	7.58 ± 0.02
Carbohydrate	2.17 ± 0.02

Note: *Data were expressed as mean ± standard deviation (SD)

The color values (L*, a*, b*) of sacha inchi pressed-cake (SPC)

The color values (L*, a*, b*) of the SPC were 81.18, 3.00 and 21.06, respectively as shown in Table 2. The SPC characteristic ranged from yellow to light brown.

Table 2. The color values (L*, a*, b*) of sacha inchi pressed-cake (SPC).

Color values	SPC
L*	81.18 ± 0.02
a*	3.00 ± 0.01
b*	21.06 ± 0.04

Note: *Data were expressed as mean ± standard deviation (SD)

Total phenolic content and antioxidant activities of sacha inchi pressed-cake (SPC)

TPC and antioxidant activities by DPPH, FRAP and ORAC of SPC were 54.29 mg GAE/100 g, 122.53, 189.41 and 2,907.55 µmol TE/100 g, respectively (Table 3).

Table 3. Total phenolic content (TPC) and antioxidant activities of sacha inchi pressed-cake (SPC).

Antioxidants	SPC
TPC (mg GAE/100g)	54.29 ± 0.39
DPPH (μmol TE/100g)	122.53 ± 10.91
FRAP (μmol TE/100g)	189.41 ± 1.95
ORAC (μmol TE/100g)	2,907.55 ± 143.26

Note: *Mean ± standard deviations of triplicate sample

The compositions of tuile without sacha inchi pressed-cake (TWSPC) and tuiles with sacha inchi pressed-cake (TSPC)

The moisture protein and fat contents of TSPC are shown in Table 4. The moisture, protein and fat contents increased when SPC levels increased ($p \leq 0.05$).

Table 4. Chemical compositions of tuile without sacha inchi pressed-cake (TWSPC) and tuiles with sacha inchi pressed-cake (TSPC).

Composition (%)	SPC : Wheat flour			
	Tuile without SPC	50:50	60:40	70:30
Moisture	2.53 ± 0.20^{d}	2.92 ± 0.11^{c}	3.81 ± 0.18^{b}	4.90 ± 0.01^{a}
Protein	6.09 ± 0.52^{d}	14.18 ± 0.28^{c}	15.43 ± 0.66^{b}	19.43 ± 0.77^{a}
Fat	20.72 ± 0.48^{d}	28.79 ± 0.27^{c}	32.82 ± 0.27^{b}	36.44 ± 0.15^{a}

Note: $^{a\text{-}d}$ Mean followed by different letters within the same row significantly differ ($P \leq 0.05$).

Physical properties of tuile without sacha inchi pressed-cake (TWSPC) and tuiles with sacha inchi pressed-cake (TSPC)

The color values (L*, a*, b*) and texture profiles of the TSPC containing different levels of SPC are shown in Table 5. The decreased L* and b* values of the tuiles indicated that substituting SPC significantly affected the lightness and yellowness of the tuiles ($P \leq 0.05$). (Figure 1).

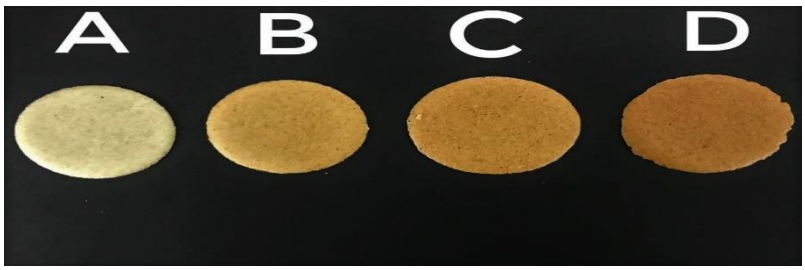

Figure 1. **Tuiles with wheat flour substituted with sacha inchi pressed-cake at 0% (A), 50% (B), 60% (C), 70% (D) by weight.**

Table 5. Color values and texture profiles of the tuile without sacha inchi pressed-cake (TWSPC) and tuiles with sacha inchi pressed-cake (TSPC).

Physical properties	SPC : Wheat flour			
	Tuile without SPC	50:50	60:40	70:30
Color values				
L*	60.16 ± 0.68^{a}	59.46 ± 0.19^{b}	57.39 ± 0.38^{c}	55.36 ± 0.53^{d}
a*	8.89 ± 0.66^{d}	13.20 ± 0.09^{c}	14.24 ± 0.30^{b}	16.38 ± 0.25^{a}
b*	40.98 ± 0.72^{a}	38.22 ± 0.11^{b}	37.24 ± 0.07^{c}	36.49 ± 0.23^{d}
Texture profiles				
Hardness (N)	1.41 ± 0.34^{d}	1.82 ± 0.14^{c}	2.23 ± 0.24^{b}	2.72 ± 0.56^{a}
Crispness (mm)	2.39 ± 0.32^{d}	2.97 ± 0.64^{c}	3.76 ± 0.49^{b}	5.43 ± 0.51^{a}

Note: $^{a-d}$ Mean followed by different letters within the same row significantly differ ($P \leq 0.05$).

Sensory properties of tuiles with sacha inchi pressed-cake (TSPC)

The sensory scores of the TSPC containing different levels of SPC are shown in Table 6. The sensory scores of 9-point hedonic scale and just about right scale of the tuiles indicated that substituting SPC significantly affected all the sensory scores of the tuiles ($P \leq 0.05$).

Table 6. Sensory scores of tuile without sacha inchi pressed-cake (TWSPC) and tuiles with sacha inchi pressed-cake (TSPC).

Treatment	Appearance[1]	Color[1]	Odor[1]	Taste[1]	Crispness[1]	Hardness[1]	Overall[1]	Color (JAR)[2]	Crispness (JAR)[3]	Sweetness (JAR)[4]
Tuiles without SPC	8.13^{b}	8.40^{a}	8.46^{a}	8.40^{a}	7.26^{a}	7.33^{a}	8.30^{a}	3.00^{c}	3.76^{a}	3.23^{a}
SPC (50%)	8.46^{a}	8.56^{a}	8.44^{a}	8.45^{a}	7.20^{a}	7.20^{a}	8.33^{a}	2.96^{c}	3.73^{a}	3.16^{a}
SPC (60%)	7.50^{c}	6.96^{b}	8.33^{a}	8.14^{a}	6.86^{b}	6.66^{b}	7.93^{b}	4.06^{b}	1.86^{b}	2.56^{b}
SPC (70%)	6.93^{d}	6.13^{c}	7.33^{b}	7.40^{b}	5.46^{c}	5.26^{c}	6.53^{c}	4.56^{a}	1.26^{c}	2.33^{b}

Note: [1] Hedonic scales: 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
[2] Color JAR: 1 = much too light, 2 = too soft, 3 = just about right, 4 = too dark, 5 = much too dark
[3]Crispness JAR: 1 = much too soft, 2= too soft, 3 = just about right, 4 = too crunchy, 5 = much too crunchy
[4]Sweetness JAR: 1 = much too little, 2 = too little, 3 = just about right, 4 = too sweet, 5 = much too sweet
Column values with the same letters were significantly different ($P \leq 0.05$).

Comparing total phenolic content and antioxidant activities of tuile without sacha inchi pressed-cake (TWSPC) and tuile with 50% sacha inchi pressed-cake

TPC and antioxidant activities by DPPH, FRAP and ORAC of TWSPC and tuile with 50% SPC are shown in Table 7. The tuile with 50% SPC showed higher TPC and antioxidant activities by DPPH, FRAP and ORAC when compared with tuiles without 50% SPC.

Table 7. Comparing total phenolic content and antioxidant activities of tuile without sacha inchi pressed-cake (TWSPC) and tuile with 50% sacha inchi pressed-cake.

Antioxidants	Values*	
	Tuile without SPC	Tuile with 50% SPC
TPC (mg GAE/100g)	42.34 ± 0.40^{b}	46.93 ± 0.38^{a}
DPPH (µmolTE/100)	53.89 ± 0.70^{b}	114.16 ± 4.27^{a}
FRAP (µmol TE/100g)	135.29 ± 0.88^{b}	158.72 ± 1.84^{a}
ORAC (µmolTE/100g)	2,243.41 ± 138.52^{b}	2,537.84 ± 104.87^{a}

Note: *Mean ± standard deviations of triplicate sample

DISCUSSIONS

Chemical compositions of sacha inchi pressed-cake (SPC)

The protein content of SPC was found to be 57.34%. These values were higher than the results reported by Saengsuk et al. (2016) (46.11%) and Kusarinkul et al. (2015) (49.79%) whereas Rawdkuen et al., (2016) reported fairly similar protein content of SPC. The variation in the protein content of SPC could be attributed to different processing and environmental conditions. The moisture and crude fiber contents were higher than the results reported by Kusarinkul et al. (2015), Rawdkuen et al., (2016) and Yuenyongputtakal et al. (2019). The ash and fat contents were fairly similar than the results reported by Kusarinkul et al. (2015) and Yuenyongputtakal et al. (2019). The carbohydrate content was lower than the results reported by Kusarinkul et al. (2015), Saengsuk et al. (2016), Rawdkuen et al., (2016) and Yuenyongputtakal et al. (2019). However, the residues left for each component in the SPC depends on the conditions applied at time of oil extraction.

Total phenolic content and antioxidant activities of sacha inchi pressed-cake (SPC)

TPC and antioxidant activities by DPPH, FRAP and ORAC of SPC were 54.29 mg GAE/100 g, 122.53, 189.41 and 2,907.55 µmol TE/100 g, respectively. The total phenolic content and antioxidant activities of SPC come from the phenolic compounds that were co-solubilized with the protein from the pressed-cake during extraction under alkali conditions (Di Bernardini et al., 2012). Chirinos et al., (2013) reported that the TPC for the sixteen sacha inchi cultivars was within the 64.6 to 80.0 mg GAE/100 g seed range, revealed flavonoid, secoridoid, and lignan type of phenolic compounds. The antioxidant activities of SPC were determined by ORAC and FRAP assays. ORAC assay is based on the hydrogen atom transfer mechanism, while the FRAP assay is based on single electron transfer (Tanasamrit et al., 2016).

The compositions of tuile without sacha inchi pressed-cake (TWSPC) and tuiles with sacha inchi pressed-cake (TSPC)

TWSPC contained 6.09% protein, while tuile 70% SPC showed the highest protein content (19.43%). There is a gradual increase in protein with increasing level of SPC. The increase in protein content could be due to SPC containing high proportion of protein (57.34%). The fat content of TSPC ranged from 20.72 to 36.44 and TWSPC showed the lowest fat content. The increase in fat content could be due to an increase proportion of SPC as SPC contains higher proportion of fat. The increase in the fat content could be a good source of energy for the elderly. Also the high fat content of the product may not provide a conducive environment for microbial growth and activities hence improving the shelf life of the tuiles (Ayo et al., 2014). The moisture content of the tuiles increased from 2.53 to 4.90% with increasing the SPC content. This could be due to the protein content increased, as protein has more affinity for moisture than carbohydrate (Ayo et al., 2014). The increase in moisture content may have been due to an increase in protein content by adding SPC in the tuiles as protein exhibits a hygroscopic nature.

Physical properties of tuile without sacha inchi pressed-cake (TWSPC) and tuiles with sacha inchi pressed-cake (TSPC)

From the results, it was noticed that the lightness (L*) and yellowness (b*) of the tuiles displayed a decreasing trend along with the increasing substitution level of SPC. The reduction of L* values indicated that the tuiles were darker in color at higher levels of substitution. The increase in redness (a*) values was noticed as SPC level in tuiles was increased. The increase in darkness of tuiles was probably because SPC was brown color and the maillard reaction and caramelization of sugar is considered to produce brown pigments during baking. These browning reactions are influenced by many factors such as water activity, sugars, type and ratio of amino compounds. Lighter color of TWSPC could be due to lesser amount of proteins leading to lesser formation of maillard compounds (Arti et al., 2016). The tuile color is an important

factor for an initial acceptability of the consumers. The hardness and crispness of TSPC significantly increased ($P \leq 0.05$) when SPC content increasing. These results were probably due to higher fiber and protein in the SPC that could have contributed to less absorption in the blend flour.

Sensory properties of tuiles with sacha inchi pressed-cake (TSPC)

As seen from the results there are significant differences ($P \leq 0.05$) among samples of the ratios of SPC for appearance, color, odor, taste, crispness, hardness and overall and JAR attributes of color, crispness and sweetness. In general fortification tuile with 50% SPC showed the highest sensory quality attributes of liking and JAR followed by the tuile with no SPC and 60% SPC tuile, while tuile with 70% SPC was rated poorest in appearance, color, odor, taste, crispness, hardness and overall. This is because of typical flavor component and caramelization of sugar in SPC during baking. (Singh et al., 2008) The tuile with 50% replacement with SPC was well accepted and not significantly different from tuile with no SPC in color. Color is a very important parameter in judging properly baked biscuits that not only reflect the suitable raw material used for the preparation but also provides information about the formulation and quality of the product. From evaluation results, tuile with 50% SPC showed the best sensory quality of liking and JAR attributes within all the tuile samples.

Comparing total phenolic content and antioxidant activities of tuile without sacha inchi pressed-cake (TWSPC) and tuile with 50% sacha inchi pressed-cake

TPC of TWSPC and tuile with 50% SPC were 42.34 mg GEA/100g and 46.93 GEA/100g, respectively. TPC was significantly increased with increasing SPC. These results indicated that adding SPC affected the TPC and antioxidant activities of tuile with 50% SPC. This could have been due to high TPC and antioxidant activities in SPC, resulting in increased TPC and antioxidant activities in tuile with 50% SPC.

CONCLUSION

Substitution of wheat flour with SPC at levels 50:50, 60:40 and 70:30% resulted in a notable increase in protein content, which could be nutritionally beneficial for the elderly as protein malnutrition is one common problem. Tuile with 50% SPC was selected to be further developed because the color score did not significantly differ from TWSPC ($P > 0.05$) Thus, SPC had a potential to enrich the nutritional value of tuiles.

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