Fortification of calcium in Thai green curry paste

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Abstract

Green curry paste is the key ingredient of Thai chicken green curry which is the most popular curry in Thailand and widely consumed in all socioeconomic classes. The average calcium intake in Thailand is lower than the Thai Recommended Daily Intake (Thai RDI). Green curry paste appears to be the most suitable vehicle for calcium fortification to meet calcium requirements. The survey study was conducted to determine the mineral content of both green curry paste and Thai chicken curry. Six levels of fortified curry paste were studied including at 19%, 25%, 30%, 40%, 50% and 60% of Thai RDI (800 mg). Calcium lactate and calcium lactate gluconate were the calcium sources. Physico–chemical properties and sensory evaluation were used to evaluate the qualities. Storage stability was also evaluated. The results showed that Thai chicken curry contains low level calcium content (64 mg/serving) and the green curry paste also had a low level of calcium (15 mg/serving). Adding calcium significantly increased the lightness and slightly decreased the pH of the fortified green curry paste. The maximum level of calcium gluconate and lactate added were considered acceptable at 19% and 40% respectively by the sensory evaluation. After the 11 week storage period, approximately 2–3% calcium loss at 30°C storage compared to 1.4–1.6% calcium loss at 4°C storage. The temperature of storage had no effect on the color of the fortified products. The fortified products with both calcium lactate and gluconate were demonstrated to last for more than 11 weeks with standard qualities (compared to Thai community product standard No. 129/2546).

Keywords: calcium lactate, calcium lactate gluconate, Thai curry paste, Thai chicken green curry

1. Introduction

Adequate calcium intake is very important for building peak bone mass in the first three decades of life and for attenuating loss of bone in later years. Besides the prevention of osteoporosis, adequate calcium intake has been associated with reduced risk of hypertension, colon cancer, kidney stones, and lead absorption (McCarron and Heaney, 2004). The average calcium intake in Thailand was found to be lower than the Thai recommended Daily Intake

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(Thai RDI) (800 mg/day). The average calcium intake of adults who live in urban and rural areas has also been reported to be 265–361 mg/day (Komindr *et al*., 1991; Pongchaiyakul *et al*., 2008) which may contribute to an increased risk of developing osteoporosis (Mahan and Escott, 2004). The data also indicated that the habitual diet of the rural Thai population may not provide enough calcium as needed for the prevention of bone loss (Pongchaiyakul *et al.*, 2008).

Achieving the recommended calcium intake is difficult for those who do not include dairy products with every meal) Lanou *et al.,* 2005; Rajeshwari *et al.,* 2004. (Fortification of foods such as orange juice, carbonated beverages, yeast breads and breakfast cereals has been used to help improve calcium intake (Fairweather and Teucher, 2004; Cerklewski, 2005; Babarykin *et al.,* 2004). An alternative and potentially more effective approach would be to fortify the traditional foods of the Thai population with calcium.

Gaining popularity all over the world, curry is a staple dish of Thailand and in many Thai homes it is eaten on a daily basis. A Thai curry dish is preferably made from curry paste, water or coconut milk, meat, seafood, vegetables or fruit. Among them, the key ingredient of Thai curry is the curry paste which is composed of five to seven distinct spices and herbs. It is a blend of spices and condiments and is used for flavoring, deodorizing, pungency, coloring, and enhancing taste. There are various types of curry pastes in Thailand including green, red, yellow, massaman and sour curry paste which are also commonly available in the market. In this context, curry paste appears to be the most suitable choice as a vehicle for calcium fortification to meet calcium requirements since it is widely consumed in all socioeconomic classes.

The survey study on the nutritional value of Thai food for health by Somsri (Institute of Nutrition, Mahidol University, 1991) among Thais aged between 20–60 year old (n=595) in different regions of Thailand showed that the most popular coconut milk based curry is chicken green curry (93%) while the most popular water based carry is sour curry (spicy fish curry) known as Kaeng Som (84%). Green curry paste is made with ingredients which include green chillies, galangal (Thai ginger), peppercorns, lemon grass, corinader roots, shallots, garlic, kaffir lime leaves and the soup is composed of coconut milk, eggplant, pea aubergine, yard long beans, and Thai basil leaves. The sour curry paste consists of a few simple ingredients including fresh and dried chillies, garlic, salt, shrimp paste (Kra-pi) and the soup consists of fish (or other seafood) and typically one kind of vegetable (or fruit).

Many factors must be considered such as cost effectiveness, solubility, acceptability of taste and appearance of finished products. Typically calcium does not have an overwhelming effect on a fortified flavor, but in a bland system, certain flavor arises. The calcium chemicals

commonly used as supplements and in fortified foods are calcium salts including calcium carbonate, calcium lactate, calcium citrate, calcium lactate gluconate and calcium sulfate (Chaiwanon, 2001). Calcium lactate (CL) and calcium lactate gluconate or calcium gluconate (CLG) are considered to be the blandest of the calcium salts, and have a good solubility (Chitpan, 2003). The purposes of the studies were to evaluate the feasibility of producing curry paste fortified with adequate levels of calcium using calcium lactate and calcium gluconate and to evaluate the storage period test of fortified products.

2. Materials and Methods

2.1 Screening test of mineral content of curry and curry paste

The purpose of this phase was to know the nutritive value in terms of mineral levels, especially of calcium, of the most popularly consumed curry; i.e. green curry and sour curry and the curry pastes. The food samples including green curry, sour curry, green paste and sour paste were collected from 3 community markets in Amphur Muang, Phitsanuloke district, Thailand. In each market, a total of 9 servings from each of the curries and each of 3 sellers were purchased. Each food sample was weighed, then the inedible portions such as inedible fish or chicken bones and shell were separated and the samples were reweighed. All edible portions were pooled, mixed and homogenized by electric blender (Brun type 4262, Germany). They were kept at -20°C for further analysis.

2.2 Preparation of curry paste and curry

The curry paste consisted of a mixture of 35% dried chili pepper (*Capsicum annuum*), 18% garlic bulb (*Allium vineale*), 18% shallot bulb (*Allium cepa*), 9% fresh lemon grass (*Cymbopogon citrates*), 4% fresh galangal (*Alpinia galangal*), 2% dried kafferlime peel (*Citrus hystrix*), 2% dried pepper seed (*Piper nigrum*), 4% tree basil, 4% shrimp paste, and 4% salt. All ingredients were mixed in electric blender (Brun type 4262, Germany) to get the green curry paste and it was freshly prepared for study. The chicken green curry was prepared based on a serving size of curry (200g) per a serving of curry paste (15 g). The green curry paste were added to coconut milk and vegetables including egg plant, basil leaves, long fed pepper, fresh kaffir lime leaves and chicken for cooking the chicken green curry.

2.3 Types and level of fortification

The two calcium sources include calcium lactate (18.35% Ca) and calcium lactate gluconate or calcium gluconate (9% Ca) with 99% purity obtained from Union Chemical 1986, Ltd, Bangkok, Thailand. The criteria for selecting fortificants were solubility and a neutral taste. The level of calcium fortification based on a 15 g serving size of curry paste and it was added at 19–60% of Thai RDI to evaluate their feasibility to be used to fortify curry paste. The chicken green curries made from fortified curry pastes were also evaluated based on sensory evaluation.

2.3.1 Development of fortification

Using the blender (Brun type 4262, Germany), the curry paste was thoroughly mixed with either calcium lactate or calcium gluconate based on the 15 g serving size calculation of the curry. Since calcium could be lost from the mixing process, fortification of the curry paste with calcium at 19, 25, 30 and 40% of Thai RDI (800 mg) per serving was pre-tested to evaluate the optimum amount of each type of calcium to meet the required calcium content.

2.4 Sensory evaluation

Using the 9-point hedonic scale, the perceptions of fortified and unfortified green curry paste and the chicken green curry that was made by the fortified curry paste were elicited from 30 volunteers who were asked to evaluate the products without tasting the products; visual evaluation only. Finally, the appropriated levels of calcium-fortified curry paste selected were evaluated for acceptability in terms of appearance, color, flavor, taste and overall acceptance based on of the chicken green curry using a 9 point hedonic scale (from like extremely = 9 to dislike extremely = 1).

2.5 Quality analyses

2.5.1 Physical properties

The fortified curry pastes were tested for physical properties including (i) color as the Cielab coordinate (L*, a*, b*) using spectrocolorimeter Model JS 555 Japan, (ii) water activity using a water activity instrument, Novasina mik 3000 (Switzerland), (iii) pH by using pH meter mode; DH340 (Germany).

2.5.2 Chemical properties

The moisture content of curry paste and curry were determined by the AOAC method (2000) and calcium content was determined in the Atomic Absorption spectrophotometer after being ashed in a muffle at 550°C following Chitpan *et al.,* (2005).

2.6 Storage stability test of calcium fortified green curry paste

The two types of green curry paste samples fortified with calcium gluconate and calcium lactate at 19% of and at 40% of Thai RDI, respectively, were selected to evaluate their storage stability. Approximately 100 g of each fortified curry paste was packed in nylon laminated PE plastic bags that are normally used commercially. After the bags were sealed, they were stored at the testing storage temperature including at room temperature (30°C) and refrigerator temperature (4°C) for 11 weeks. The products were periodically sampled at 1 week and later every 2 week to determine the physical and chemical properties and the microbiological test including total viable count by pour plate (A.O.A.C (1990)), E.*coli* by MPN (A.O.A.C (1990)), yeast and mold by Rose bengal agar (Pouch *et al.,* 2001).

3. Results and Discussion

It has previously been shown that calcium (Ca) deficiency is common in the Thai population (Komindr *et al.,* 1991; Pongchaiyakul *et al.,* 2008). The calcium intake has been observed to be at a low level as the habitual diets do not include dairy products which are the major source of calcium (Pongchaiyakul *et al.,* 2008). Fortified foods offer alternative sources of calcium to traditional foods to meet the calcium requirement. In this study green curry paste was selected as the vehicle as it is the key ingredient of Thai chicken green curry which is the most popular curry in Thailand and widely consumed in all socioeconomic classes. Two commercial calcium salts were used for calcium enrichment; calcium gluconate and calcium lactate which were chosen due to their solubility and neutral taste.

3.1 The mineral contents of curries and curry pastes from the community markets.

In Thailand, chicken green curry (CGC) is the most popular coconut milk based curry while the sour curry (spicy fish curry) (SC) called Kaeng Som, is the most popular water based carry (Somsri *et al.,* 1991, Institute of Nutrition, Mahidol University). The results of the quantity survey of the mineral content of these curries from three community markets at Amphur Muang, Phitsanuloke district is shown in Table 1. Based on a 200 g serving size of curry, calcium, potassium, phosphorus and magnesium contents of both curries were much lower than the Thai Recommended Dietary Intake (Thai RDI). However, regarding to each 3 serving size per day, sodium levels were quite high for SC (1,054 mg/serving size) and CGC (1,083 mg/ a serving size), respectively, compared with the recommended level (2,400 mg a day). We also found low levels of calcium in both sour curry (13 mg/serving) and green curry (15 mg/serving) pastes from the three community markets. To achieve daily calcium requirements, the result found here indicated that fortifying curry paste with calcium additives is required to

increase the calcium content in the curry to appropriate daily levels of intake. In this study, green curry paste was considered to be the best model for investigating the possibility of calcium-fortified curry paste because we wonder if the coconut milk which is commonly added to the chicken green curry not sour curry affects the fortified paste.

Table 1 Mineral contents of the curries from the three community markets at Phitsanulok province.

Samples	Minerals contents(mg/100g)				
	Calcium (Ca)	Potassium (K)	Magnesium (Mg)	Phosphorus (P)	Sodium (Na)
Sour curry (SC)	32.52±0.95	140.24±1.42	16.18±0.03	32.34±0.47	527.71±0.32
Chicken green curry (CGC)	32.04±7.58	185.55±5.73	22.60±0.45	68.15±2.56	541.56±27.32
*Thai RDI (mg/day)	800	3,500	350	800	2,400

Note: *Thai RDI (mg/day) is the Thai Recommended Daily Intakes for ages of 6 years and up

3.2 The calcium fortification level

3.2.1 Physical properties

Regarding the Thai regulations for claims about nutrition, the terms ”high” or ”rich in” are allowed to describe individual vitamins or minerals that are present at 20% or more of the Thai RDI reference amount, while the term ”good source” or ”contains” is used for such nutrients present at 10%–19% of the reference value (Regulation No 182). Therefore, six levels including 19%, 25%, 30%, 40%, 50% and 60% of the Thai RDI were used to study the potential maximum level of calcium fortification of green curry paste without spoiling the curry’s color, flavor or aroma. Table 2 shows the color and pH of the fortified curry paste. The L* value indicates that the color of the fortified curry paste was comparatively brighter than that of the control sample of unfortified product. The color of CLG fortification significantly increased in white tone compared with the CL fortified product. Compared with the unfortified product, the fortified products had a greenish-yellow color (lesser a* and more b* value) and the product fortified with CL tended to be more green (lesser a* value) than the one fortified with CLG. Both CLG and CL slightly lowered the pH of the products from 5.3 to 5.10–5.23, but they had no effect on the water activity of the products (data not shown). Approximately, the maximum level (60% added) of CL and CLG caused the pH of the products to change from 5.3 to 5.2 and 5.1 respectively. Sigh *et al*. (2007) also reported that both CLG and CL resulted in a decrease in the pH of milk.

Table 2 Color and pH of green curry pastes fortified with different calcium salts

Fortified Level (%)	[1]CL fortified				[2]CLG fortified			
	**L*	a*	b*	pH	L*	a*	b*	pH
0	37.94±0.05^{e}	0.51±0.09^{a}	20.39±0.14^{e}	5.30±0.04^{a}	37.94±0.05^{g}	0.51±0.09^{a}	20.39±0.14^{g}	5.30±0.04^{a}
19	36.78±0.05^{f}	0.51±0.13^{a}	21.41±0.30^{d}	5.15±0.01^{de}	53.45±0.08^{f*}	-0.17±0.27^{b}	26.40±0.06^{b}	5.10±0.00^{d}
25	36.64±0.21^{f}	0.22±0.18^{a}	21.82±0.34^{c}	5.17±0.01^{cde}	56.07±0.14^{e}	0.31±0.20^{a}	26.85±0.04^{a}	5.28±0.02^{ab}
30	38.63±0.76^{d}	0.69±0.12^{a}	23.47±0.22^{b}	5.13±0.01^{e}	59.08±0.03^{d}	-0.23±0.02^{b}	25.72±0.07^{c}	5.26±0.00^{b}
40	49.12±0.24^{c}	-0.64±0.61^{b}	24.60±0.09^{a}	5.23±0.00^{b}	64.33±0.10^{c}	-0.63±0.27^{c}	23.88±0.14^{d}	5.17±0.00^{c}
50	52.61±0.23^{b}	-1.39±0.44^{c*}	24.68±0.20^{a}	5.20±0.01^{bc}	65.31±0.16^{b}	-0.26±0.14^{b}	23.03±0.03^{e}	5.13±0.00^{cd}
60	54.98±0.33^{a}	-2.47±0.46^{d*}	24.66±0.09^{a}	5.18±0.02^{cd}	68.12±0.10^{a}	-0.88±0.15^{c*}	21.37±0.23^{f}	5.10±0.00^{d}

Note: [1]CL mean calcium lactate

[2]CLG mean calcium lactate gluconate

** L* = 0 mean BLACK, 100 mean WHITE;

a* = + mean RED, - mean GREEN;

b* = + mean YELLOW, - mean BLUE

[a–g] means within the same column followed by different letters were significant different (p<0.05)

3.2.2 Consumer perceptions of the calcium fortified curry paste and the chicken green curry

Calcium compounds often impart a chalky, gritty mouth feel, off-flavors and undesirable coloration (Singh *et al.,* 2007). Therefore, sensory evaluation was carried out. The perceptions of fortified and unfortified green curry paste and the chicken green curry that was made by the fortified curry paste were elicited from 30 volunteers who were asked to evaluate the products without tasting the products; visual evaluation only. The result from Table 3 indicated that compared to the control (0% adding), CL fortification did not affect the consumers' perception of the curry paste in terms of appearance, color, flavor and overall acceptability, while CLG fortification at the level of 60% did affect the overall acceptability of the product.

Table 3 Consumer perceptions of fortified green curry paste with calcium lactate and calcium lactate gluconate

Fortified Level (%)	[1]CL fortified				[2]CLG fortified			
	appearance	color	flavor	Overall acceptability	appearance	color	flavor	Overall acceptability
0	6.60±1.05^{a}	6.26±1.43^{ab}	6.33±1.04^{ab}	6.40±1.18^{ab}	6.60±1.05^{a}	6.26±1.43^{ab}	6.33±1.04^{ab}	6.40±1.18^{ab}
19	6.60±0.98^{a}	6.33±1.11^{a}	6.46±1.40^{a}	6.86±1.24^{a}	6.53±1.06^{ab}	6.20±0.77^{ab}	6.40±1.24^{a}	6.40±1.40^{ab}
25	6.73±1.16^{a}	6.33±1.39^{a}	6.60±1.24^{a}	6.93±0.88^{a}	6.60±0.82^{a}	6.26±0.59^{ab}	6.33±1.17^{ab}	6.40±1.24^{ab}
30	6.66±1.23^{a}	6.53±1.40^{a}	6.60±0.91^{a}	6.53±1.12^{ab}	6.60±0.98^{a}	6.20±1.20^{ab}	6.20±1.14^{ab}	6.33±1.17^{ab}
40	6.53±0.74^{a}	6.26±0.88^{ab}	6.46±0.99^{a}	6.33±0.97^{ab}	5.86±1.50^{abc}	5.86±1.59^{ab}	6.20±1.69^{ab}	6.20±1.01^{ab}
50	6.33±0.89^{ab}	6.20±1.01^{ab}	6.33±0.89^{ab}	6.26±0.79^{ab}	5.60±1.45^{bc}	5.80±1.20^{ab}	5.93±0.96^{ab}	5.73±0.96^{bc}
60	5.93±1.22^{abc}	6.06±1.03^{ab}	6.06±1.33^{ab}	6.13±1.18^{ab}	5.26±1.66^{c}	5.20±1.15^{b}	5.33±1.54^{b}	5.06±1.18^{c}

Note: [1]CL mean calcium lactate

[2]CLG mean calcium lactate gluconate

$^{a–d}$ means within the same column followed by different letters were significant different (p<0.05)

However, the results shown in Table 4 demonstrate that CL significantly affected the overall acceptability of the chicken green curry made with the curry paste that was fortified with calcium lactate at a level of 40% and greater. CLG also significantly impacted the flavor and the color of the curry made by the curry paste fortified with CLG at a level of 30% or greater. Therefore, the chicken green curry made by the CL fortified curry paste at the level of 19%–40% and the CLG fortified curry paste at the level of 19–30% were selected for study by sensory evaluation. The results of the sensory evaluation of the curries are shown in Tables 5 and 6.

The curry made with the curry paste fortified with CLG at the level of 25% and 30% scored significantly lowest in taste and overall acceptability (Table 5), therefore, the CLG fortification at the level of 19% is considered to be suitable for calcium fortification and was selected for the storage stability test. On the other hand, the score of the curries made with curry paste fortified with CL at each level had no significant differences (Table 6). The curry paste fortified with CL at the level of 40 % was, therefore, selected for the storage stability test. Based on the acceptance of the curries cooked by the fortified green curry paste, the results here revealed that the maximum level of CLG and CL that could be added to curry paste while retaining acceptable sensory attribute of the curry are 19% and 40%, respectively.

Table 4 Consumer perceptions of chicken green curry made by the fortified curry paste with calcium at different levels

Fortified Level (%)	[1]CL fortified				[2]CLG fortified			
	appearance	color	flavor	Overall acceptability	appearance	color	flavor	Overall acceptability
0	7.20±1.14^{a}	7.26±0.96^{a}	7.20±0.94^{a}	7.40±0.91^{a}	7.20±1.14^{a}	7.26±0.96^{a}	7.20±0.94^{a}	7.40±0.91^{a}
19	6.73±1.03^{ab}	6.46±1.24^{abc}	6.26±1.09^{ab}	6.73±0.96^{abc}	6.53±1.30^{ab}	6.53±1.30^{abc}	6.80±1.08^{ab}	6.73±1.09^{abc}
25	6.60±0.98^{ab}	6.26±1.16^{bcd}	6.20±1.01^{b}	6.46±0.99^{bcd}	6.53±1.24^{ab}	6.53±1.25^{abc}	6.60±1.05^{ab}	6.73±1.16^{abc}
30	7.20±1.01^{a}	6.86±1.30^{ab}	6.60±1.18^{ab}	7.06±1.22^{ab}	6.40±1.12^{ab}	6.13±0.74^{bcd}	6.13±1.12^{b}	6.53±0.83^{abcd}
40	5.93±1.27^{b}	5.40±1.35^{d}	6.06±1.22^{b}	6.00±1.13^{cd}	6.46±1.06^{ab}	6.20±1.26^{bcd}	6.26±1.16^{ab}	6.53±1.06^{abcd}
50	6.00±1.30^{b}	5.66±1.44^{cd}	5.93±1.43^{b}	5.86±1.24^{cd}	6.20±1.08^{b}	6.06±1.16^{bcd}	6.06±1.09^{b}	6.06±1.03^{cd}
60	5.80±1.14^{b}	5.53±1.35^{cd}	6.00±1.13^{b}	5.73±1.38^{d}	6.78±1.09^{ab}	6.13±1.18^{bcd}	6.26±1.03^{ab}	6.40±1.05^{bcd}

Note: [1]CL mean calcium lactate

[2]CLG mean calcium lactate gluconate

$^{a-d}$ means within the same column followed by different letters were significant different (p<0.05)

Table 5 Sensory evaluations of chicken green curry made by the fortified curry paste with calcium lactate gluconate (CLG) at different levels

Fortified levels (%)	Chicken green curry by CLG fortified curry paste				
	appearance	color	flavor	taste	Overall acceptability
0	6.96±1.06^{a}	7.10±0.84^{a}	6.96±0.76^{a}	6.96±0.55^{a}	7.06±0.78^{a}
19	6.83±0.79^{a}	6.73±0.90^{ab}	6.80±1.15^{ab}	6.86±0.97^{ab}	6.76±0.93^{a}
25	6.76±0.81^{a}	6.96±0.80^{ab}	6.63±0.96^{ab}	6.50±0.92^{b}	6.39±0.95^{b}
30	6.30±0.87^{b}	6.50±1.10^{b}	6.40±0.93^{b}	6.50±0.68^{b}	6.23±1.16^{b}

Note: $^{a-b}$ means within the same column followed by different letters were significant different (p<0.05)

Table 6 Sensory evaluations of chicken green curry made by the fortified curry paste with calcium lactate (CL) at different levels

Fortified levels (%)	Chicken green curry by CL fortified curry paste				
	appearance	color	flavor	taste	Overall acceptability
0	7.00±0.64[ab]	6.80±0.80[ab]	7.03±0.92[a]	6.90±1.09[a]	6.96±0.66[ab]
19	6.56±1.16[b]	6.66±1.02[b]	6.80±0.84[a]	6.63±0.88[a]	6.63±0.96[b]
25	6.90±0.80[b]	6.53±0.81[b]	7.10±0.75[a]	6.70±1.02[a]	7.00±0.94[ab]
30	7.00±0.78[ab]	6.73±0.78[ab]	6.90±0.99[a]	6.60±1.10[a]	6.83±0.94[ab]
40	7.16±0.91[a]	7.16±1.01[a]	6.93±0.94[a]	6.46±1.10[a]	7.30±0.95[a]

Note: [a-b] means within the same column followed by different letters were significant different (p<0.05)

3.2.3 The storage stability test of calcium fortified green curry paste

The green curry pastes fortified with CL at the level of 40% and with CLG at the level of 19% were used for the storage stability test. During the 11 week storage period, moisture content, water activity, color value, calcium contents and the microbiological levels of fortified products were determined. After 11 weeks, the 30°C storage caused the lightness (L* value) of the CLG fortified curry pastes to be significantly decreased but there was no significant difference for the 4°C storage tests. However there were no significant differences of the L* value and a value for the CLG fortified products stored at 30°C and 4°C but the b value of the CLG fortified product kept at 30°C was significantly lower than the one kept at 4°C. The result indicated that the 19% CLG fortified green curry paste is better kept at 4°C rather than 30°C

For the CL fortified product, there were no significant differences of L*, a* or b* value for the 30°C storage while there were significantly decreased levels of L*, a* and b* values for the 4°C storage. This suggested that the 40% CL fortified green curry paste is better kept at 30°C in terms of color stability.

As the storage period proceeded, calcium contents of the fortified products significantly decreased. For the room temperature storage at 30°C, calcium content of the CLG and CL fortified products significantly decreased from 2,856.21 to 2,769.78 mg/100g (dw) and from 6,461.93 to 6,332.90 mg/100g (dw), respectively (p<0.05). For the refrigerator temperature storage of 4°C, the calcium content of both the CLG and CL fortified products also significantly decreased from 2,828.33 to 2,788.28 mg/100g and 6,331.27 to 6,228.48 mg/100g (dw), respectively (p<0.05). The loss of calcium in the fortified products at refrigerator temperature (1.4–1.6%) were slightly less than the one at room temperature (2–3%). Calcium is a stable nutrient that normally is lost by leaching. Loss of calcium during storage, dying and cooking is

not likely to occur, since calcium would not be destroyed by oxidation and heat treatment (Clydesdale, 1991).

Compared with the water activity of the CLG (aw 0.886) and CL (aw 0.882) fortified products at day 0, the 11 week storage period for both at 30°C had no significant effect on the water activity of either the CLG (0.879) or the CL (0.880) fortified products. It might be because the packaging material is normally a good barrier against moisture. The results were found to be the same for both products at the temperature storage of 4°C. The total bacteria amounts after the 11 week storage period were less than 10^6 cfu/g, which is under the food regulation allowable level (Figure 1). In addition, coliform bacteria, yeast and mold amounts were less than log 3 MPN/g and 100 cfu/g respectively and these results were still under the Thai community product standard No. 129/2546 allowable levels. The same result was also observed in the commercial green curry paste purchased from a local seller. The curry paste can be classified as low acid food (pH 5.4–5.6), having high water activity, making it a highly perishable product. However, the microbiological results in terms of total plate count of coliform bacteria and the combined count of yeast and mold of the test products seemed to contradict the fact that the product should have spoiled, given the high level of water activity in these products. The explanation for this phenomenon is that the herbs used, including chili, shallot (red onion) and garlic, which are the main ingredients in curry paste, are natural antimicrobial and antioxidant compounds (Nishimura *et al.,* 2000; Shelef, 1983).

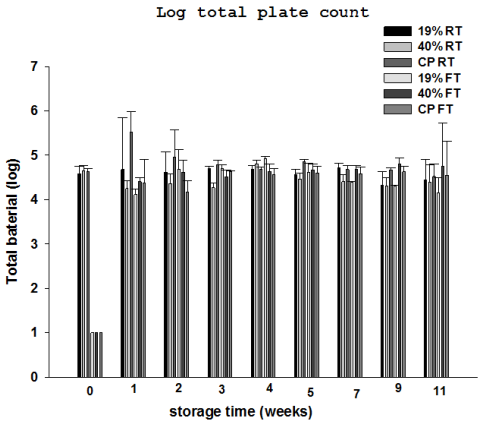

Figure 1 The total plate count of 19% CLG fortified curry paste and 40% CL fortified curry paste during 11 week storage at 4°C and 30°C; RT = 30°C, FT= 4°C, CP = the commercial curry paste without fortification

4. Conclusion

Green curry paste can be successfully fortified with calcium lactate and calcium gluconate. In regard to the Thai regulations on nutrition claims in edible products regarding mineral content, the CLG fortified green curry paste in this study can be claimed as a 'good source' of calcium or the claim of 'contains' calcium, while CL fortified products can be claimed as being 'rich in' or 'high in' calcium since the maximum level of CLG was 19% while that of the CL was 40%, while maintaining the acceptability and palatability of the chicken green curry made with the fortified curry paste. Based on the quality requirements of the Thai community product standard (No. 129/2546), the calcium fortified products can be stored at either room or refrigerator temperature for 11 weeks.

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Table 7 Color of fortified curry pastes packaged in plastic bag during 11 week storage; at 30°C and at 4°C

Storage period (week)	30°C						4 °C					
	[2]CLG 19%			[1]CL 40%			CLG 19%			CL 40%		
	**L*	a*	b*	L*	a*	b*	L*	a*	b*	L*	a*	b*
0	±41.740.53[a]	0.18±0.94[a]	0.34±15.44[a]	0.18±39.34[b]	±0.340.03[a]	±14.360.13[a]	±41.740.53[b]	0.18±0.94[a]	0.34±15.44[a]	0.18±39.34[a]	±0.340.03[a]	±14.360.13[a]
11	0.54±40.39[b]	0.12±0.74[b]	0.17±15.03[a*]	0.07±39.00[b]	0.01±0.29[a*]	0.07±14.14[a*]	0.16±40.10[b]	0.02±0.71[b]	0.12±15.41[a*]	0.17±38.91[b]	0.02±0.05[b*]	0.21±12.76[b*]

Note: [1]CL mean calcium lactate

[2]CLG mean calcium lactate gluconate

[a-b] means within the same column followed by different letters were significant different (p<0.05)

** L* = 0 mean BLACK, 100 mean WHITE;

a* = + mean RED, - mean GREEN;

b* = + mean YELLOW, - mean BLUE

Table 8 Calcium content of fortified curry paste packaged in plastic bag during 11 week storage time.

Storage period	30°C		4°C	
(week)	CLG 19%	CL 40%	CLG 19%	CL 40%
0	2856.20±11.55^{a*}	6461.93±1.49^{a}	2828.33±0.81^{a}	6331.27±1.45^{a}
1	2819.05±2.25^{e}	6227.27±1.58^{g}	2786.55±1.38^{d}	6229.28±0.90^{d}
2	2811.96±1.05^{f}	6223.36±0.61^{h}	2774.46±57.84^{b}	6142.18±0.71^{h}
3	2853.26±0.80^{b}	6269.2±0.77^{e}	2831.21±0.82^{a}	6176.62±0.77^{g}
4	2822.07±1.29^{d}	6402.77±0.92^{b}	2832.28±0.55^{a}	6203.97±0.67^{f}
5	2849.46±0.74^{c}	6333.40±0.84^{d}	2788.85±1.30^{b}	6304.15±0.56^{c}
7	2709.24±0.33^{h}	6248.34±0.28^{f}	2770.98±0.63^{b}	6313.23±0.39^{b}
9	2820.60±1.21^{de}	6341.78±0.14^{c}	2846.90±0.64^{a}	6214.79±0.30^{e}
11	2769.78±0.17^{g}	6332.90±1.73^{d}	2788.28±1.30^{b}	6228.48±0.59^{d}

Note: [1]CL mean calcium lactate

[2]CLG mean calcium lactate gluconate

[a–g] Means within the same column followed by different letters were significant different (p<0.05)

* Significant difference among group for the same color value (p<0.05)

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