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Anti-aging and Health Benefits from Thai Food: Protective Effects of Bioactive Compounds on the Free Radical Theory of Aging

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Abstract

Traditional food is an important representative for each country. Thai dishes are appreciated not only by people in Thailand but also worldwide. The unique flavor, meticulous preparation, and dish decorations of Thai food certainly reflects the background, culture, tradition, and characteristics of Thailand. In addition to its deliciousness, Thai food is also recognized as a healthy and functional diet. Various healthy ingredients, such as local vegetables, home-grown culinary herbs, and spices are usually contained in Thai dishes. The biological activities of ingredients in Thai foods, including antioxidant, anti-inflammatory, and antimicrobial effects suggest that the appropriate consumption of such a diet can influence the anti-aging process. Hence, the recipes of selected famous Thai dishes are described regarding their ingredients, phytochemicals, phytonutrients, and biological activities associated with anti-aging effects. Furthermore, the free radical theory related to aging and the possible role of Thai food in health benefits are also discussed for a more comprehensive explanation of the anti-aging effects of Thai diets.

Introduction

Food is an intangible part of a nation's cultural heritage which embodies its country's background, characteristics, and tradition. The legacy of national food and cooking develops from the beginning of a nation's history. Thailand is one of the oldest countries in the world and accordingly has a long history, a unique culture, and delicious food. Today, foreigners associate Thailand with its remarkable Thai cuisine. With Thai food's strong reputation for flavor and meticulous preparation, Thai cuisine has been known internationally for over a decade. The unique flavor of Thai food is a balance of different tastes, including sour, sweet, salty, and spicy (Nitiworakarn, 2014). The variety and flavor of Thai food differs among the four different regions of Thailand: North, Northeast, Central, and South. Thai food recipes have been modified slightly to satisfy the palate of people coming from

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different parts of Thailand and foreign countries. However, all the main ingredients, preparation procedures, and signatures of each dish remain the same (Nitiworakarn, 2014). Thai ancestors emphasized not only the taste of food but also its health benefits, using knowledge from Thai folk tradition to create many healthy and delicious dishes for prolonging lifespan and maintaining good health and bodily functions (Sirisunthorn, 2013). Various vegetables, home-grown culinary herbs, and spices are always present in Thai dishes. These ingredients are rich in nutrients with medicinal properties. The biological activities of Thai culinary herbs and spices have been demonstrated in many studies including antioxidant (Tangkanakul & Trakoontivakorn, 2014), anti-inflammatory (Sirikanokvilai et al., 2014), antibacterial (Nugboon & Intarapichet, 2015), antihyperglycemic (Wongsa et al., 2012), and hypocholesterolemic effects (Duangjai et al., 2011). Because of the information mentioned above, Thai food has been accepted as a healthy and functional diet (Singsomboon, 2015).

Today, the progression of medical care and technology increases human life expectancy. However, this longevity is normally accompanied by aging, chronic and age-related diseases, undesirable physical traits, memory loss, and a decline in physical and physiological functions (Ho et al., 2010; Scapagnini et al., 2016). Accordingly, most people attempt to have a healthy lifestyle and prevent the onset of age-associated diseases including physical deterioration. Cosmetic surgery and the intake of synthetic vitamins and/or food supplements seem to be top strategies that have been chosen and used for those purposes. Those strategies and other similar approaches may provide a youthful appearance or the desired aesthetic results in a short time, but such changes are not sustainable. The keystone of successful aging is having good health. Good nutrition combined with regular physical activity is one of the most common practices for obtaining and maintaining good health.

The consumption behavior of most people is quite different from that in the past. Increasingly rushed lifestyles cause most people choose to consume fast food, takeaways, or ready-to-eat meals instead of home-prepared food for the sake of convenience (Sirichakwal et al., 2015; Townshend & Lake, 2017). These foods provide poor nutrition and are high in meat, carbohydrates, and fat. A poor diet affects a person's health and can contribute to untimely aging and age-related diseases (Willcox et al., 2009). In recent years, health-consciousness has risen worldwide. To achieve a longer and healthier life, many people have changed their consumption behavior by consuming more wholesome diets (Chang, 2014; Waratornpaibul, 2014). In addition to Mediterranean (Renna et al., 2015) and Okinawan diets (Willcox et al., 2009), Thai food is among the healthiest and most functional diets. Consuming Thai dishes helps maintain good health and postpone the aging process and is suitable for people of any age or gender. Therefore, this review is focused on the anti-aging and health benefits of Thai diets. The recipes of selected popular Thai foods and some essential ingredients used in those recipes are described. In this context, the biological activities and bioactive components of these selected dishes and their condiments, in addition to the free radical or oxidative stress theory of aging and the possible role of Thai food in anti-aging and health benefits are also discussed.

Famous Thai foods

Thai food is characterized by full-flavored dishes. Both Thais and foreigners are fascinated by its exotic and intense flavors. Thai dishes are high in vegetables and low in glycemic index, red meat, and fat. Many Thai foods consumed by foreigners are favored for their taste and health benefits. In this review, several famous Thai foods and dessert (Fig. 1) are selected from recipes that are commonly consumed in Thailand and their popularity among foreigners (Cable News Network, 2017) and described. Some essential ingredients used in the recipes for these dishes are summarized in Table 1. The active components and the biological activities exhibited by the essential ingredients are also presented.

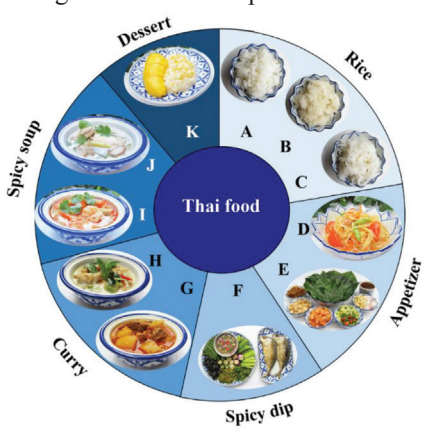

Fig. 1 Selected famous Thai foods: (A) steamed non-glutinous rice, (B) steamed glutinous rice, (C) rice noodle, (D) spicy green papaya salad, (E) wild betel leaf wraps, (F) spicy shrimp paste dip, (G) Massaman curry, (H) green curry, (I) hot and sour soup, (J) coconut milk soup with galangal, and (K) sweet sticky rice and ripe mango.

1. Rice

Most Thai dishes are served with cooked rice (*Oryza sativa* L.). For example, non-glutinous (Fig. 1A) and glutinous (Fig. 1B) rice and other rice products, and rice noodle (Fig. 1C) are an important part of Thai meal. Specifically, Thai dishes are usually accompanied by steamed non-glutinous rice, while steamed glutinous rice is often served with regional dishes from Northern and Northeastern Thailand. Rice noodle or "Kanom Jeen" is served along with Thai coconut milk-based curries. Rice, a staple food as well as an economic crop of Thailand, acts as a major source of carbohydrates in Thai meals. It also provides protein, lipids, dietary fiber, vitamins, essential amino acids, minerals, and bioactive compounds (Lim, 2013; Nakornriab, 2018). Many rice cultivars have been cultivated for domestic consumption and exports, which Thai jasmine rice or "Hom Mali rice" is the most well-known rice cultivar (Rice Department, 2016). Many studies have reported the diverse biological activities of rice. Grains of white, red, and black rice exhibit antioxidant effects at different levels. The bioactive compounds in black rice grains, including catechin, cyanidin-3-glucoside, and peonidin-3-glucoside play an important role in the antioxidant activity (Jiamyangyuen et al., 2017). Protocatechuic acid contributes to the antiproliferative activity of cooked Thai purple rice (Chatthongpisut et al., 2015) and anti-inflammatory potential of cooked black rice (Bhawamai et al., 2016). Ethanolic extracts of white and colored rice grains exhibit an antiglycation effect (Daiponmak et al., 2014) that is beneficial to the management and treatment of diabetes (Ramkissoon et al., 2013). Therefore, the low glycemic index (GI) rice cultivars are being bred concerning health and diabetes (Vanavichit, 2015). Phenolic compounds are responsible for the anti-advanced glycation end product (AGE) activity, resulting in the reduction of cellular oxidative damage (Daiponmak et al., 2014). Hence, the nutritional, anti-aging, and health benefits of Thai food arise not only from the cooking ingredients but also from rice.

2. Appetizers

For example, Thai style appetizers consist of various fresh vegetables such as cucumbers, tomatoes, yard-long beans, culinary herbs, tamarind and lime juices, garlic, shallot, and chili pepper. The sour and sweet flavors combined with a touch of spiciness of Thai appetizers can increase appetite.

2.1 Spicy green papaya salad or "Som Tam"

Spicy green papaya salad has spread from the Northeast region to other parts of Thailand. A basic recipe of spicy green papaya salad contains shredded green papaya, garlic cloves, yard-long beans, wild tomatoes, dried shrimps, and roasted unsalted peanuts (Fig. 1D). Other ingredients such as salted eggs, fresh blue swimmer crabs, and crispy fishes are added to the basic recipe to create new varieties of this Thai-style salad. This dish is seasoned with fish sauce, palm sugar, tamarind and lime juices, and chili peppers. The large amount of dietary fiber from fresh vegetables accompanied by the organic acids from the tamarind and lime juices can help improve gastrointestinal function (Padayachee et al., 2017) and defecation (Bhardwaj et al., 2014). Garlic possesses various phytochemicals that play an important role in its biological effects including organosulfur compounds or thiosulfinates and flavonoids (Corzo-Martínez, et al., 2007; Bayan et al., 2014). Some of the notable antioxidant activities of garlic result from quercetin (Nuutila et al., 2003) and diallyl disulfide (Chekki et al., 2014), while catechin, vanillic acid, and ferulic acid are responsible for its anti-inflammatory effects (Moutia et al., 2016). The immunomodulatory activities of fructooligosaccharides isolated from aged garlic extracts has been demonstrated *in vitro* (Chandrashekara & Venkatesh, 2016). Allicin and other *Allium* thiosulfinates exhibit antihypertension activity in hypertensive patients (Bhardwaj et al., 2015) and show α-glucosidase inhibitory effects in diabetic rats (Al-Malki, 2016). Moreover, carpaine in the flesh of green papaya also has strong inhibitory effects against both α-amylase and α-glucosidase. There is also scientific evidence supporting the use of papaya for type 2 diabetes treatment, which originated from Nigerian folk medicine (Oboh et al., 2013).

2.2 Wild betel leaf wraps or "Miang Kham"

Wild betel leaf wraps are healthy appetizers. Many Thai culinary herbs are used as the main ingredients in the recipe. This one-bite appetizer usually consists of wild betel leaves, roasted coconut flakes, small lime wedges, roasted unsalted peanuts, dried shrimp, small pieces of ginger, chili peppers, shallots, and a sauce made from shrimp paste and palm sugar (Fig. 1E). To prepare this dish, a betel leaf is rolled into a cone shape, and all the ingredients are put into it. Then, one teaspoon of sauce is added on top. Many scientists have studied the phytochemicals and biological activity of wild betel leaves. The flavonoids rutin and vitexin in wild betel leaves exhibit antioxidant efficacy by protecting human umbilical vein endothelial cells from oxidative stress (Ugusman et al., 2012). The anti-inflammatory and antipyretic effects of wild betel leaf have also been

demonstrated in rats (Ridtitid et al., 2007). Shallots are rich in well-known antioxidants including, allicin, quercetin, anthocyanins, and kaempferol (Swamy & Gowda, 2006). Dipropyl disulfide and dipropyl trisulfide play an important role in the antioxidant and antimicrobial activity of the essential oils (Mnayer et al., 2014) and extracts (Raeisi et al., 2016) of shallots. The anti-inflammatory (Mohammadi-Motlagh et al., 2011), immunomodulating (Mlcek et al., 2016), anti-obesity (Woon & Toh, 2014), anti-hypertensive (García-Trejo et al., 2016), and hypoglycaemic (Luangpirom et al., 2013) effects of shallots have also been reported. Furthermore, the antispasmodic effect of ascalonicoside B on the isolated guinea pig ileum supports the use in traditional Thai medicine of shallot for alleviating gastrointestinal disturbance (Corea et al., 2005). Ginger is another potent source of antioxidants. The major phenolic compounds found in fresh ginger rhizomes are gingerols and its analogues, the shogaols (Koch et al., 2017), which contribute to the antioxidant and anti-inflammatory effects (Dugasani et al., 2010). Ginger has been found to exhibit antidiabetic and antihyperlipidaemic activities (Jafarnejad et al., 2017), analgesic potential (Darvishzadeh-Mahani et al., 2012), and gastroprotective effects (Chantharangsikul et al., 2016).

3. Spicy dip

Thai spicy dip is an indispensable dish in all four regions of Thailand, as it provides spicy, sour, sweet, and salty flavors. The common ingredients of Thai dipping sauces are chili pepper, garlic cloves, and shallot. The varieties of spicy dip and the other ingredients vary depending on regions and types of diet. For instance, Central cuisine uses shrimp paste to enhance the saltiness and intenseness of the dipping sauces, while fermented fish are used in Northeastern cuisine (Sirisunthorn, 2013) and fermented soybean paste are used for replacing shrimp paste in the vegetarian dipping sauces (Wittanalai et al., 2011). Various types of fresh and cooked vegetables are typically served along with this menu as a side dish. Interestingly, more than one hundred different recipes for spicy dip have been listed in Thai cookbooks since the Ayutthaya era (Sirisunthorn, 2013).

Spicy shrimp paste dip or "Nam Phrik Ka Pi" is a signature dish of the Central region of Thailand. It is made from shrimp paste, garlic cloves, shallots, chili peppers, and turkey berry and is flavored with lime juice, fish sauce, and palm sugar. This dipping sauce is often served along with fried Thai mackerels and vegetables (Fig. 1F). Shrimp paste, which is made from fermented krill or mysid shrimps, contains essential and non-essential amino acids especially, glutamate, aspartate, lysine, and leucine (Chotechuang, 2012; Kleekayai et al., 2015). Thai shrimp paste has shown strong antioxidant and angiotensin I-converting enzyme (ACE) inhibitory activities (Kleekayai et al., 2015). Capsaicinoids cause the hot, spicy, and pungent tastes of chili peppers (Barbero et al., 2016) and have remarkable antioxidant and anti-inflammatory activities (Chen et al., 2015). The extracts of chili peppers exhibit immunostimulant (Yamaguchi et al., 2010), antidiabetic (Nantakornsuttanan et al., 2016), and neuroprotective (Watcharachaisoponsiri et al., 2016) effects. Turkey berry, a small *Solanum* fruit, has been discovered to exhibit strong antioxidant and antihyperlipidaemic effects (Gupta & Gohain, 2015) and anti-inflammatory (Rammohan & Reddy, 2010), antihypertension (Mohan et al., 2009), and hepatoprotective (Ramamurthy et al., 2016) activity. Thai spicy dip is always served with local vegetables such as Asiatic pennywort, bitter cucumber, and water morning glory (Tharasen & Lawan, 2012), the edible parts of which contain strong antioxidants including β-carotene, xanthophyll, and zeaxanthin. Interestingly, another potent antioxidant, lutein, is found in only the young stems of water morning glory (Tharasen & Lawan, 2012).

4. Coconut milk-based curry

Curry pastes and coconut milk are the relevant ingredients of Thai coconut milk-based curry. Thai curry pastes are a mixture of various culinary herbs and spices including garlic, shallot, coriander root and seed, galangal rhizome, lemon grass, kaffir lime peel, chili pepper, peppercorn, and cumin seed. Curry pastes are named according to the color of these main condiments and additional essential ingredients used in each recipe. Coconut milk is important ingredient of Thai curry. It is an oil-in-water emulsion pressed from the solid endosperm of coconut (Raghavendra & Raghavarao, 2010). Thai folk wisdom uses it as a liquid medium in many Thai food recipes, particularly curries and soups. Coconut milk serves as a natural solvent during food preparation by extracting both polar and non-polar compounds from various herbs and spices in Thai curry pastes (Sapabguy & Yasurin, 2015). Thai curry paste extracted with coconut milk has higher antimicrobial activity than that extracted with water (Lazuardi et al., 2012). Coconut milk itself is rich in nutrients and phytochemicals such as protein, fatty acids, and phenolic compounds (Nadeeshani et al., 2015) and has exhibited antioxidant effects (Alyaqoubi et al., 2015). The phenolic

compounds such as ellagic, *p*-coumaric, and ferulic acids contribute to the antioxidant activity of coconut milk (Nadeeshani et al., 2015). The low-molecular-weight proteins isolated from coconut milk have the antimicrobial effects against microbes, *Debaryomyces hansenii,* and *Candida albicans* (Algar & Mabesa, 2015).

4.1 Massaman curry or "Kaeng Massaman"

Massaman curry is one of the most famous Thai curries (Fig. 1G). It is a mild coconut milk-based soup containing peanut, potato, and pineapple that provides delicate sweet, salty, and sour flavors. Massaman curry is made with yellow onions, potatoes or sweet potatoes, roasted peanuts, pineapple, Siam cardamoms, bay leaves, cinnamon sticks, and Massaman curry paste. Generally, either beef or chicken is used in the preparation of Massaman curry. Tamarind juice, palm sugar, and fish sauce are added for seasoning. Traditional Thai medicine uses pineapple to aid in the process of digesting meat. Cardamoms and bay leaves help deodorize the smell of meat in Massaman curry. The antioxidant efficacy of Siam cardamom arises from the compound kravanhin B (Yin et al., 2013). In Thailand, the bay leaves in Thai Massaman curry are from *Cinnamomum porrectum.* This bay leaf-like condiment contains abundant phenolic acids and exhibits antioxidant activity (Saetan et al., 2016). Massaman curry paste, which contains plentiful antioxidant-rich spices (Table 1), has demonstrated strong antioxidant activity in vitro (Siwarungson & Lertpringkop, 2016). Various phytochemicals are derived from Massaman curry paste, including gallic acid, cinnamaldehyde, and eugenol from clove (Embuscado, 2015; De La Torre Torres et al., 2017); myristophenone from mace and nutmeg; rhamnetin from peppercorn (Embuscado, 2015); linalool from coriander seed; cinnamon stick and bay leaf (De La Torre Torres et al., 2017); cuminaldehyde from cumin seed; oleoresin from chili pepper; and quercetin and kaempferol from shallot and garlic (Peter, 2006). Numerous studies have reported the health benefits of the culinary herbs and spices contained in Massaman curry, including antioxidant (Masuda et al., 2015), anti-inflammatory (De La Torre Torres et al., 2017; Opara & Chohan, 2014), and hypoglycaemic, antidiabetic, and antipyretic activities (Peter, 2006).

Table 1 Culinary herbs and spices composed in selected Thai foods.

Ingredients	Scientific name	Appetizer		Spicy dip	Curry		Soup		Dessert
		Spicy green papaya salad	Wild betel leaf wraps	Spicy shrimp paste dip	Massaman curry	Green curry	Hot and sour soup	Coconut milk soup with galangal	Sweet sticky rice and ripe mango
Herbs									
Chili pepper	*Capsicum annuum*	✓	✓	✓		✓	✓	✓	
Chili spur pepper	*Capsicum annuum*					✓			
Coriander leaf	*Coriandrum sativum*						✓	✓	
Coriander root	*Coriandrum sativum*				✓	✓	✓		
Galangal rhizome	*Alpinia galanga*				✓	✓	✓	✓	
Garlic	*Allium sativum*	✓		✓	✓	✓			
Ginger	*Zingiber officinale*		✓						
Kaffir lime leaf	*Citrus hystrix*					✓	✓	✓	
Kaffir lime peel	*Citrus hystrix*					✓			
Lemon grass	*Cymbopogon citratus*				✓	✓	✓	✓	
Lime	*Citrus aurantifolia*	✓	✓	✓			✓	✓	
Sweet basil leaf	*Ocimum basilicum*					✓			
Tamarind	*Tamarindus indica*	✓							
Shallot	*Allium ascalonicum*		✓	✓	✓				
Yellow onion	*Allium cepa*				✓				
Spices									
Bay leaf	*Cinnamomum porrectum*				✓				
Cinnamon	*Cinnamomum spp.*				✓				
Clove	*Syzygium aromaticum*				✓				
Coriander seed	*Coriandrum sativum*				✓	✓			
Cumin seed	*Cuminum cyminum*				✓	✓			
Dried chili spur pepper	*Capsicum annuum*				✓				
Mace	*Myristica fragrans*				✓				
Nutmeg	*Myristica fragrans*				✓				
Peppercorn	*Piper nigrum*				✓	✓			
Siam cardamom	*Amomum krervanh*				✓				

Remark: The symbol (✓) indicates ingredients used in recipe.

Table 1 Culinary herbs and spices composed in selected Thai foods. (Continued)

Ingredients	Scientific name	Appetizer		Spicy dip	Curry		Soup		Dessert
		Spicy green papaya salad	Wild betel leaf wraps	Spicy shrimp paste dip	Massaman curry	Green curry	Hot and sour soup	Coconut milk soup with galangal	Sweet sticky rice and ripe mango
Vegetables									
Coconut flake	*Cocos nucifera*		✓						
Brinjal	*Solanum aculeatissimum*					✓			
Aubergine	*Solanum melongena*					✓			
Green papaya	*Carica papaya*	✓							
Turkey berry	*Solanum torvum*			✓		✓			
Yard-long bean	*Vigna unguiculata*	✓							
Wild betel leaf	*Piper sarmentosum*		✓						
Wild tomato	*Solanum lycopersicum*	✓							
Fruits									
Pine apple	Ananas comosus				✓				
Ripe mango	*Mangifera indica*								✓
Others									
Coconut milk	*Cocos nucifera*				✓	✓		✓	✓
Shrimp paste	*Acetes spp.*		✓	✓	✓	✓			

Remark: The symbol (✓) indicates ingredients used in recipe.

4.2 Green curry or "Kaeng Khiao Wan"

Green curry is a greenish coconut milk-based soup that has a medium spicy taste. It is usually served with either steamed rice or rice noodle. Thai eggplants, turkey berry, sweet basil leaves, kaffir lime leaves, fresh chili spur peppers, and green curry paste are the basic ingredients of this curry, which can be made with pork, beef, chicken, fish, or seafood. Thai green curry made with chicken is the most popular variety among both Thai people and foreigners (Fig. 1H). The condiments of Thai green curry paste are shown in Table 1. *In vitro* studies have demonstrated the antioxidant effect (Siwarungson & Lertpringkop, 2016) and anti-inflammatory activity (Sirikanokvilai et al., 2014) of digested Thai green curry. The flavonoids and phenolic compounds in the culinary herbs composing green curry paste are responsible for its antioxidant and anti-inflammatory activities (Settharaksa et al., 2012). Thai eggplant, an edible fruit of the genus *Solanum,* has three varieties that can be used in green curry preparation: brinjal, aubergine, and turkey berry. Various studies on the biological activities of these *Solanum* fruits, including the antioxidant and antihaemolytic potential of a protease inhibitor in brinjal (Meenu Krishnan et al., 2015), anti-inflammatory activity of the flavonoids, sterols, and saponins in turkey berry (Rammohan & Reddy, 2010), antidiabetic and antihypertension effects of the phenolic compounds in green aubergine (Kwon et al., 2008), and cardioprotective activity of nasunin in aubergine (Das et al., 2011). Sweet basil leaf has an anise-like aroma. Active compounds including rosmarinic acid and essential oils contribute to its potent antioxidant activity (Avetisyan et al., 2017), anti-inflammatory and antigenotoxic capacities (Güez et al., 2017), and hypolipidaemic effect (Touiss et al., 2017).

5. Spicy soup

Spicy soup normally contains lemon grass, fresh galangal rhizome, kaffir lime leaves, and coriander roots. It is garnished with coriander leaves and flavored with fish sauce, lime juice, and chili peppers. Thai soup is typically made with some basic culinary herbs and ingredients and is used in curry. The difference between Thai soup and Thai curry is that the shrimp paste is not used as one of the main ingredients in any recipes of Thai soup. In traditional Thai medicine, the consumption of spicy soup can relieve the fever and gastrointestinal disturbance. Lemon grass, kaffir lime leaves, and galangal rhizome are responsible for the antipyretic property and ability to act as a gastrointestinal remedy of spicy soup (Sirisunthorn, 2013). Thai spicy soups are divided into two types based on the appearance of the liquid medium, which can divide Thai spicy soup into two types: clear soups and creamy soups. The latter type is made with coconut milk or evaporated milk.

5.1 Hot and sour soup or "Tom Yam"

Hot and sour soup is one of the most famous Thai dishes (Fig. 1I). The variety of this soup depends on the choice of meat, which can include shrimp, beef, pork, chicken, fish, and seafood. Interestingly, all of the ingredients and mixed pastes of hot and sour soup have potent antioxidant and antimicrobial effects (Siripongvutikorn et al., 2005). The fresh culinary herbs in hot and sour soup are a rich source of antioxidants, including β-carotene from chili peppers and kaffir lime leaves (Siripongvutikorn et al., 2005); chlorogenic acid, isoorientin, and swertiajaponin from lemon grass (Campos et al., 2014); and naringin and vitamin C from

lime juice (Boshtam et al., 2011). Lemon grass (Campos et al., 2014) and kaffir lime leaves (Laohavechvanich et al., 2010) exhibit protective effects against oxidative damage in human umbilical vein endothelial cells (HUVECs) and HepG2 cells, respectively. The anti-inflammatory properties of lemongrass result from its luteolin glycosides (Francisco et al., 2014) and essential oil (Boukhatem et al., 2014). The hepatoprotective effects of lemongrass extracts have been demonstrated in rats as well (Arhoghro et al., 2012; Saenthaweesuk et al., 2017).

5.2 Coconut milk soup with galangal or "Tom Kha"

Coconut milk soup with galangal is a coconut milk and galangal-based soup (Fig. 1J). It is similar to hot and sour soup in both main ingredients and flavors. However, compared to hot and sour soup, this soup has a milder taste and contains chili pepper. The taste of the dish is a combination of salty, sour, and sweet flavors arising from fish sauce, lime juice, and coconut milk, respectively. The antioxidants mainly originated from galangal rhizome, lemon grass, kaffir lime leaves, chili peppers, and coconut milk (Ayusuk et al., 2009). Galangal, a key ingredient of this soup, exhibits different biological activities that have important health benefits. The antioxidant activity of galangal has been determined (Ayusuk et al., 2009), and the presence of gallic acid and ellagic acid in galangal extracts contributes to their antioxidant effects (Nampoothiri et al., 2015). Galangin, an abundant phytochemical in galangal rhizomes (Kaur et al., 2010), plays an important role in anti-inflammatory (Baldo & Serrano, 2016), antidiabetic (Sivakumar et al., 2010), anti-obesity, and antihyperlipidemic activities (Kumar & Alagawadi, 2013). Another potent anti-inflammatory agent, 1′-acetoxychavicol acetate is also presented in galangal rhizomes (Ichikawa et al., 2006).

6. Dessert

Most Thai desserts are made from sugar, rice, rice products, and coconut. Coconut milk, in addition to the mature flesh and the water of young coconut, has been used in the preparation of Thai sweets for a long time. Tropical fruits in Thailand, such as mango, banana, and durian, are also used as the main ingredients in many Thai dessert recipes.

Sweet sticky rice and ripe mango or "Khao Niao Mamuang" is one of the best summer desserts in Thailand. Sliced ripe mangoes are served with steamed sticky rice that is mixed in thick coconut milk and sugar, covered with extra thick coconut milk, and sprinkled with roasted mung bean (Fig. 1K). Thai mangoes have a unique aroma and a mild sweet flavor. They are usually served in both Thai restaurants and street food markets. The flesh of ripe mango possesses many powerful antioxidants including, mangiferin, ellagic acid, β-carotene, and vitamin C (Oliveira et al., 2016). Mango flesh extracts have demonstrated antioxidant (Kim et al., 2010) and anti-inflammatory (Kuganesan et al., 2017) effects, which result in part from the presence of mangiferin (Pardo-Andreu et al., 2008; Gong et al., 2013) and ellagic acid (Favarin et al., 2013; Kilic et al., 2014). The antigenotoxic and cytoprotective activities of mangiferin have also been confirmed in vivo (Viswanadh et al., 2010).

Aging processes and Thai food

Thai nutritionists have suggested that the intake of Thai diets could affect the aging process and help maintain good health. The bioactive compounds and phytochemicals in Thai dishes have been claimed to play an important role in their anti-aging effects and health benefits (Nitiworakarn, 2014; Sirisunthorn, 2013). However, one question that is raised from this information, "How does Thai food affect the aging process?" needs to be clarified. The understanding of aging and how it occurs would help answer this question.

1. What is aging?

All living organisms, including humans, cannot avoid aging. Aging is a progressive biological process that causes considerable functional deterioration of the human body, such as declining physical and physiological functions, memory loss, and increased disease vulnerability (Ho et al., 2010). Normally undesirable physical traits, such as grey hair, skin wrinkles, patchy and sagging skin, and dark spots, are signs of aging (Cannon, 2015; Calasanti et al., 2016). Humans try to understand the aging process and use the obtained knowledge to delay the onset of aging. Different theories have been proposed for the explanation of this natural process. The free radical or oxidative stress theory is one of the main hypotheses and could be used to simplify the explanation of how aging occurs.

Oxygen-centered free radicals or reactive oxygen species (ROS) are unstable molecules containing unpaired electrons. They rapidly react with other substances to neutralize themselves (Lobo et al., 2010). These unstable molecules attack all types of biomolecules, including proteins, lipids, and nucleic acids, via redox

reactions, thereby leading to aging, mutations, cellular damage, and cell death (Vaiserman et al., 2016). Free radicals are involved in chronic illnesses and age-associated diseases (Daiponmak et al., 2014). ROS such as hydroxyl, peroxyl, and superoxide radicals originate from both internal and external sources (Durak, 2014; Bhattacharya, 2015). Cellular metabolism, especially the electron transport chain in mitochondria, inflammatory response, and phagocytosis, are the main endogenous ROS generators (Scapagnini et al., 2016). The exogenous sources include environmental pollutants, cigarette smoking, chemicals, radiation, and high energy diets full of high sugar, protein, and fat-containing foods (Lobo et al., 2010). Normally, the human body has both enzymatic and non-enzymatic antioxidant defense systems to maintain the balance between free radicals and antioxidants by eliminating excess ROS (Urquiza-Martínez & Navarro, 2016). A large amount of ROS and insufficient antioxidative defense systems cause the accumulation of free radicals in cells, which causes oxidative stress and oxidative damage (Momtaz & Abdollahi, 2012). Many studies have reported the substantial function of oxidative stress in the aging process and cellular senescence. Cellular oxidative damage including the damage of mitochondrial DNA, DNA, and the cell membrane; loss of structural integrity; and protein dysfunction also contributes significantly to age-related and chronic diseases, especially type 2 diabetes, hypertension, atherosclerosis, cardiovascular diseases, and cancer (Fig. 2) (Scapagnini et al., 2016; Daiponmak et al., 2014). These diseases are more harmful than undesirable physical traits.

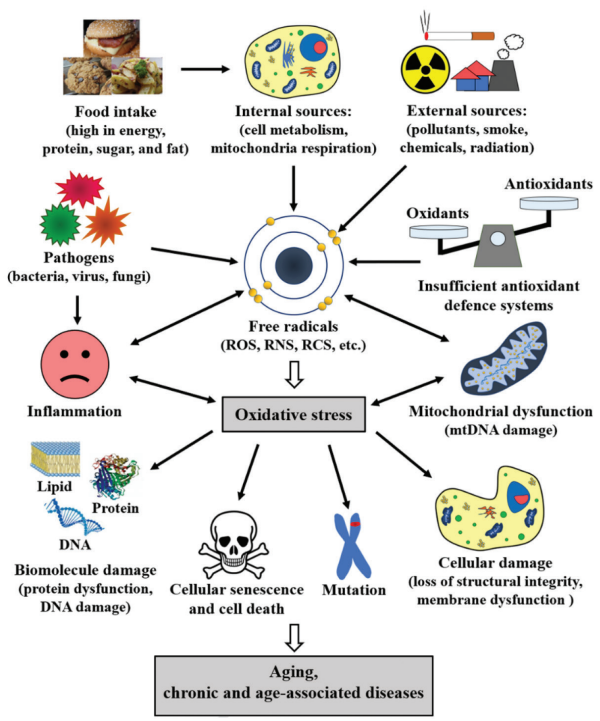

Fig. 2 Proposed mechanism of the free radical or oxidative stress theory of aging

Fig. 2 shows that free radicals are produced by both internal and external sources. The imbalance between free radicals and antioxidants in favor of free radicals results in oxidative stress. Excessive free radicals interact with biomolecules and cells, thereby causing aging, mutations, cellular damage, cell death, chronic illness, and age-associated diseases. ROS: reactive oxygen species, RNS: reactive nitrogen species, RCS: reactive chlorine species.

2. How does Thai food affect the aging process?

Reducing the excess free radicals in human body can delay the aging process and reduce the risk of chronic and age-related diseases. Antioxidants can decrease the level of excess free radicals and protect cells from oxidative damage by scavenging, neutralizing, deactivating, or stabilizing free radicals before they can react with biomolecules and cells (Bhattacharya, 2015; Urquiza-Martínez & Navarro, 2016). Natural antioxidants present in the human body include glutathione (GSH), pyruvate, superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx) (Momtaz & Abdollahi, 2012). However, oxidative stress frequently occurs because the antioxidant defense systems are not capable of eliminating the excess ROS, thereby resulting in the imbalance between ROS and antioxidants. Therefore, exogenous antioxidants from different sources are supplemented to either diminish ROS or elevate the efficiency of the endogenous antioxidant systems.

Exogenous antioxidants originate from a person's daily diet. Food ingredients such as vegetables, spices, and fruits are a rich source of plant-derived antioxidants. Plant-derived antioxidants in diets are mainly phenolic compounds, flavonoids, and vitamins. These compounds can be divided into water-soluble and lipid-soluble antioxidants (Lobo et al., 2010). Well-known hydrophilic antioxidants include vitamin C or ascorbic acid, anthocyanins, catechins, and gallic acid, while vitamin E or α-tocopherol, β-carotene, and quercetin are the most prominent representatives of lipophilic antioxidants (Scapagnini et al., 2016; Asif, 2015). By acting as hydrogen donors, electron donors, radical scavengers, or

singlet oxygen quenchers, these antioxidants can maintain the amount of cellular ROS at a non-toxic level thereby reducing oxidative stress and cellular oxidative damage (Lobo et al., 2010; Bhattacharya, 2015). Trace elements from diets, including iron (Fe), selenium (Se), copper (Cu), manganese (Mn), and zinc (Zn) from diets, are essential cofactors for antioxidant enzymes. For instance, Cu/Zn, Fe, and Se are required for the optimum catalytic activity of SOD, CAT, and GPx respectively (Vural et al., 2010). Natural, semi-synthetic, or synthetic antioxidants are delivered to consumers in the form of dietary supplements. However, these supplements supply only antioxidants while excluding other nutrients. The excessive intake of instant antioxidants could have adverse effects on human health because of their pro-oxidant activities (Yordi et al., 2012). Food offers appropriate amounts of both natural antioxidants and nutrients that are necessary for maintaining bodily functions and good health.

Thai food is a very healthy and functional diet. As indicated by the descriptions the explanations of selected Thai dishes provided above, Thai food is a rich source of nutrients and antioxidants. Based on the oxidative stress theory of aging, the antioxidants derived from Thai diets can help increase the level of cellular antioxidants, eliminate excess oxidants, prevent free radical formation, and break the chain reaction of oxidative stress (Lobo et al., 2010; Vaiserman et al., 2016; Bhattacharya, 2015).

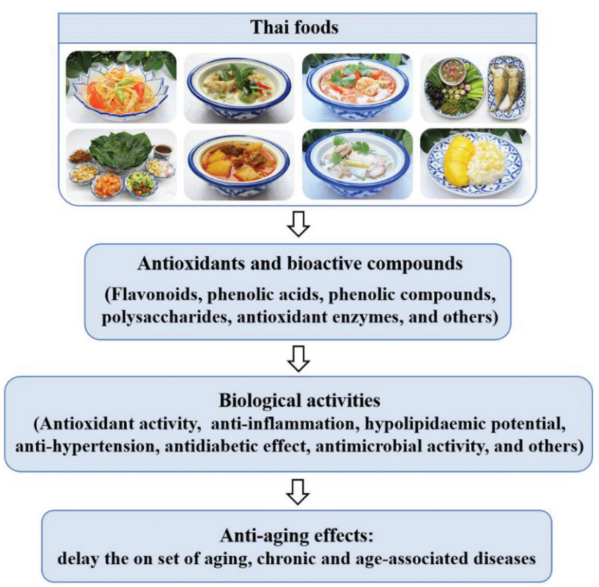

Fig. 3 The role of antioxidants and bioactive compounds derived from antioxidant-rich and healthy diets in anti-aging effects.

Fig. 3 shows that exogenous antioxidants eliminate excess oxidants, enhance endogenous antioxidative defense systems, and maintain the balance between oxidants and antioxidants. The biological activities of antioxidants and bioactive compounds influence the aging process and reduce the risk of chronic and age-associated diseases. Micronutrients contained in some ingredients, such as Se in garlic (Corzo-Martínez, et al., 2007), Fe in shallot (Swamy & Gowda, 2006), and Zn in rice (Lim, 2013), also optimize the catalytic activity of endogenous antioxidant enzymes (Vural et al., 2010). This information indicates that the consumption of Thai food can influence the aging process by balancing the level of oxidants and antioxidants in cells and increasing the efficiency of the endogenous antioxidant systems. Moreover, it suggests that Thai food can delay and/or prevent the onset of age-associated diseases and age-related chronic illness.

Conclusion

Ultimately, the classic quote "You are what you eat" is true. A person's consumption behavior always reflects the health conditions of that person. In addition to good taste, the health benefits of diets have recently been taken into consideration as well as good tastes. Thai food is a healthy diet providing both intense flavors and health benefits, including anti-aging effects. In this context, many studies have indicated the role of Thai food and its healthful ingredients in anti-aging and maintaining good health. The antioxidants and bioactive compounds of condiments comprised in Thai dishes diminish free radicals in human body resulting in the reduction of oxidative stress the postponement of the aging process. The explanations and scientific evidence of antioxidants, bioactive compounds, and biological activities associated with the anti-aging efficacy of Thai food described in this review suggest that consuming Thai foods may delay the onset of aging and prevent the development of age-related and chronic diseases.

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