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Quality of Thai Furikake dried seasoning powder fortified with natural calcium and phosphorus

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ORIGINAL ARTICLE

Abstract

Fresh Liang leaves, a local vegetable of Southern Thailand, were dried, seasoned, and fortified with different ratios of dried shrimp and sesame seeds at 1%–5% for making a rice topping product (Furikake) named as F1-F5. The F5 obtained the highest consumer acceptability with high calcium and phosphorus contents at 4,299.45 mg/kg and 3,436.32 mg/kg, respectively. Total phenolic content and DPPH radical scavenging antioxidant activity of F5 were 2,575.22 µg GAE/g DW and 676.99 µg TE/g DW, respectively. Total chlorophyll and carotenoid contents were 11.38 mg/g DW and 3.52 mg/g DW, respectively. An increment of a_w and moisture content ($p < 0.05$) of the F5 kept at higher temperature storage was noticed, and a reduction of L* value under all storage conditions was noticed.

Keywords: daily seasoning powder (Furikake); calcium; phosphorus; total phenolic content

Introduction

The quality of human lives is determined by diet and lifestyle. Increment awareness and consciousness about health lead to the development of functional food or healthier food items (Chhikara *et al.*, 2018; Panghal *et al.*, 2018). However, non-communicable chronic diseases (NCDs) are a global health problem, accounting for 70% of deaths in developing countries (Osuna-Padilla *et al.*, 2019). In addition, cardiovascular diseases are the main cause of mortality worldwide (Benjamin *et al.*, 2018). An association has been reported between eating habits and the progression of metabolic disorders and NCDs (Centers for Disease Control, 2003). It is well known that processed foods usually contain fewer nutritional compounds, particularly fiber, vitamins, and minerals, with high fats, carbohydrates, and additives leading to increased risk of NCDs such as diabetes type II, cardiovascular disorders, high blood pressure, and cancers (Kumar, 2019; Liu, 2003). Some processed foods or snacks tried to provide bioactive substances including fiber, chlorophyll, phenolics, and antioxidant activity which help reduce oxidative stress, inflammation, and blood glucose (Suksanga *et al.*, 2023a,b). Convenience foods or ready-to-eat products are now popular due to busy lifestyles. Therefore, busy people improve their lives by eating healthier foods, with cross-cultural connections and increasing globalization leading to the fusion of eating styles and habits. Thailand is famous for street food, which is available in trolleys, shacks, shelters, and small and large restaurants which provide local and international cuisines including Japanese food like sushi and sashimi. Even Japanese and Thai food may have some different manner such as taste, flavor, and portion, there is more blended and harmonized such as seasoning, topping, and blending styles. Furikake means to sprinkle in Japanese and is commonly used as seasoning for cooked plain rice or on other dishes such as bean curd and fish (Japan Centre, N.D.). Furikake usually consists of dried seaweed, roasted sesame seeds, dried fish, salt, monosodium glutamate (MSG), and sugar (Mouritsen, 2009) as a good source of calcium with umami taste. However, heavy metal contamination of seaweed, a bioindicator of marine pollution, is now a significant issue of awareness (Filippini *et al.*, 2021; Paz *et al.*, 2019). The high demand for Japanese food or eating style in Thailand has spawned many startup companies, entrepreneurs, restaurants, and some food industries that are looking for alternative indigenous raw plant material with no chemical residues from fungicides, insecticides, herbicides, and other hazard agents due to health concern and marketing reasons.

Liang (*Gnetum gnemon*) belongs to the *Gnetaceae* family, and this arboreal dioecious plant is widely cultivated in Southeast Asia (Anisong *et al.*, 2022). *Gnetum* fruits and seeds are commonly used as a vegetable in Indonesia. Seeds of the *Gnetum* plant contain 9 to 10% protein with high antioxidant activity to deter free radicals (Siswoyo *et al.*, 2011). *G. gnemon* variety *tenerum* leaves are normally consumed as a fresh vegetable, with chemicals rarely used during growth (Anisong *et al.*, 2022). The leaves contain completely essential amino (27 % DW), high fiber (36% DW), and chlorophyll (226 mg/g DW) (Siripongvutikorn *et al.*, 2023) exhibiting diabetes type II reduction by increasing Glut 4 but lowering Glut 2 which was like the used standard drug, metformin, but with less toxicity and side effects (Suksanga *et al.*, 2023). Sesame (*Sesamum indicum* L.) is a globally important oil crop, with seeds containing manganese, copper, calcium, magnesium, iron, phosphorus, vitamin B_1, zinc, and dietary fiber, together with two unique substances: sesamin and sesamolin (Sirato-Yasumoto *et al.*, 2001), which protect the liver from oxidative damage (Caulman *et al.*, 2005), while dried shrimp is a good source of calcium and has high protein content as a complete essential amino acid (Das *et al.*, 2021; Smith and Guentzel, 2010). Calcium is an essential macro element which is most often associated with healthy bones and teeth. Besides, it also plays an important role in blood clotting, helping muscles to contract, and regulating normal heart rhythms and nerve functions in human body (Harvard T.H. Chan, 2023) as well as kidney disease (Scialla and Anderson, 2013). Phosphorus is another macro mineral that works closely together with calcium to build strong bones and teeth (Takeda *et al.*, 2012). It is present in smaller amounts in cells and tissues throughout the body. Phosphorus aids to filter out waste from the kidneys and plays an essential role in how the body stores and uses energy. It also helps reduce muscle pain after a workout. In addition, phosphorus helps for the growth, maintenance, and repair of all tissues and cells, and to produce genetic building blocks, DNA and RNA. Phosphorus is also needed to help balance and make proper use of other vitamins and minerals, including vitamin D, iodine, magnesium, and zinc (Noori *et al.*, 2010; Smirnov *et al.*, 2010). However, several studies suggested that higher intakes of phosphorus can be associated with an increased risk of cardiovascular disease. Consumption of milk is a good model to ensure a delicate balance diet between calcium and phosphorus for proper bone density and prevention of osteoporosis (van Kuijk *et al.*, 2010; Takeda *et al.*, 2012).

To negate the disadvantages of processed food and increase the visibility of convenient food with health effects, this study aimed to develop Furikake Thai style, with dried seasoning using Liang leaves instead of seaweed, and the addition of dried shrimp and sesame seeds to increase calcium and phosphorus contents for the better choice of a healthy item.

Materials and methods

Preparation of Liang leaves

Liang leaves were purchased from a farmer in the Songkhla Province. The leaves were rinsed in water to remove dirt and dust before soaking in 100 ppm chlorine solution for 15 min and then rinsed twice to remove excess chlorine residue to not over than 1 ppm as standard regulation (Ministry of Public Health, 2019). The prepared sample was then blanched at 95 ± 3°C for 1 min and drained for 2 min to ensure microbial quality and facilitate the drying process.

Preparation of Thai Furikake dried seasoning powder

The pretreated leaves were blended with caster sugar, salt, soy sauce, water, and monosodium glutamate (MSG), with percentage compositions shown in Table 1, and then dried in a hot air oven at 60°C until the moisture content was lower than 10%. The dried sample called as component 1 was roughly ground to obtain particle sizes ranging from 10 to 40 mesh. Then, the prepared sample or component 1 was taken to add with dried shrimp and sesame seeds in the next step.

Fortification of dried shrimp and sesame seeds and selection

This study was conducted from an entrepreneurial viewpoint and a detailed analysis of profitable business investment potential was not provided. Component 1 was the dried- seasoned Liang leaves as stated in Table 1 while

Table 1. Percentage composition of Thai Furikake dried seasoning powder ingredients.

Ingredient	Percentage composition (%)
Pretreated Liang leaves	57.84
Caster sugar	3.81
Salt	0.92
Soy sauce	6.94
Monosodium glutamate	0.93
Water	29.56

component 2 was added with dried shrimp and sesame seeds at a 50:50 ratio. Based on preliminary test and entrepreneur selection, components 1 and 2 were later mixed at a fixed ratio of 62.5 to 37.5, the dried shrimp and sesame ratio was adjudged, as shown in Table 2, to produce five mixture formulations (F1 to F5). F1 contained the lowest amount of dried shrimp but the highest blended white and black sesame seeds, while the other mixture formulations contained more dried shrimp (a+%) and lower amounts of sesame seeds. The more added shrimp, the less sesame seeds were used as up and down ratio. Therefore, F2 contained dried shrimp and sesame seeds at a+1% and b-1%, F3 contained a+2% and b-2%, F4 contained a+3% and b-3%, and F5 contained a+4% and b-4%. Mixture formulations F1 to F5 are shown in Table 2. Each treatment was assessed for sensory attributes by 60 untrained panelists based on a 9-point Hedonic scale. The sample mixture that exhibited the highest sensory score was selected for further analysis of physical, chemical, and microbiological qualities.

Quality changes during storage

The selected Thai Furikake dried seasoning powder based on sensory acceptability was packaged in a laminated bag (PE+PET+AL) and stored at 25°C and 40°C with relative humidity levels of 60% and 90%. The samples were then subjected to a qualitative shelf-life analysis including water activity, moisture content, pH, color values, and microbiological content.

Physical properties determination

a_w value

The a_w value was determined using an AquaLab water activity meter (METER Group, Inc. USA). Each a_w measurement was recorded as the average of three determinations.

Table 2. Compositions of Thai Furikake dried seasoning powder from Liang leaves with mineral supplements.

Mixture	Mixture composition (%)	
	Coarse ground dried shrimp	White and black sesame seeds
F1	A	b
F2	a+1	b-1
F3	a+2	b-2
F4	a+3	b-3
F5	a+4	b-4

F1 contained the lowest amount of dried shrimp but the highest amount of sesame seeds, a = ground dried shrimp, b = white and black sesame seeds; F2 contained dried shrimp and sesame seeds at a+1% and b-1%, F3 contained a+2% and b-2%, F4 contained a+3% and b-3%, and F5 contained a+4% and b-4%.

Moisture content

The moisture content was determined using the oven method (AOAC, 2000). The sample was dried in an oven at 105°C for 24 hours. Moisture content was calculated from the weight difference between the original and the dried sample and expressed as a percentage of the original sample.

pH value

Five grams of each sample was mixed with distilled water at a ratio of 1:15 (dried sample: water). After mixing well, a pH meter was probed in the mixture to read and record the pH value.

Color

The product was measured using a colorimeter (Color Flex EZ, HunterLab Co., Ltd., USA) using a D65 light source with observations at 10°. Before sample measurement, a standard whiteboard and blackboard were used to calibrate the instrument. The CIELAB color space coordinates were expressed as lightness (L*), redness (a*), and yellowness (b*) with color determined by the L*, a*, and b* values.

Sensory evaluation using a 9-point hedonic scale

The sensory evaluation was conducted by 60 untrained panelists aged 18–30 years who had signed consent forms, with the ethical approved number PSU-HREC-2023-005-1-1. Approximately 1 g of the sample was served on steamed rice in plastic cups and coded randomly with three digits. The panelists were asked to evaluate the six samples for five attributes including appearance, color, aroma, taste, and overall preference. Plain drinking water at room temperature (25–27°C) was provided for mouth rinsing between samples. A score below 5 from any sample was considered unacceptable, while samples with the highest sensory scores were selected for the next experiment.

Mineral contents

Calcium and phosphorus content

Mineral determination followed by AOAC (2019) method 984.27. A 1.5 g aliquot of dried sample was mixed with 30 mL $HNO_3{\cdot}HClO_4$ (2 + 1) and left to sit overnight.

The Kjeldahl flask with the sample was heated on a mantle at low temperature with continuous heating at low temperature until HNO_3 and H_2O were vaporized. The flask was then switched to a cool heating mantle with occasional heating until digestion was completed. The reaction of $HClO_4$ and organic material was stopped when the effervescent reaction ended. Thereafter, the mixture was heated at high temperature for 2 min and then cooled. The mixture, with final acid content ($HClO_4$) at 20%, was diluted with water and left overnight. Minerals in the mixture were determined using inductively coupled plasma (ICP) emission spectroscopy (BRE731400 iCAP PRO ICP-OES, Thermo Scientific, Waltham, Massachusetts, USA) with wavelengths for calcium and phosphorus as 317.9 and 214.9 nm, respectively, and then calculated as Equation

$$C = A \times (50/B)$$

where

A = concentration (μg/mL) of element as determined by ICP.
B = volume or weight of sample as milligrams or grams.
C = elemental concentration in sample solution (μg/mL or μg/g)

Chlorophyll and carotenoid contents

Chlorophyll contents were determined following the methods of Schmalko and Alzamora (2001), and Cao *et al.* (2007). The samples (0.5 g) were extracted with 10 mL of an acetone–water solution (80:20, v/v) and then placed in an ultrasonic water bath at 15°C for 5 min. The homogenate was centrifuged at 1,789 × g or 3,000 rpm for 5 min and the supernatant was collected in a glass bottle. This process was repeated by adding acetone solution until the extract became colorless. The supernatants were collected and concentrated with a rotary evaporator before measuring at 480, 510, 645, and 663 nm by a UV-vis spectrophotometer. Chlorophyll and carotenoid contents were calculated using the equations below (Guan *et al.*, 2005).

$$\text{Chlorophyll a (mg/l)} = 12.7{*}A663 - 2.69{*}A645$$
$$\text{Chlorophyll b (mg/l)} = 22.9{*}A645 - 4.68{*}A663$$
$$\text{Total chlorophyll (mg/l)} = 20.2{*}A645 + 8.02{*}A663$$
$$\text{Carotenoids (mg/l)} = 7.6{*}A480 - 1.49{*}A510$$

Biological activity determination

Preparation of sample extract

The sample (30 g) was accurately weighed and mixed with ethyl alcohol (75 %, v/v) at a sample-to-solvent ratio of 1:300 (v/v). This mixture was sonicated at 200 W and 40 kHz using an ultrasonic bath for 30 min (KQ5200DE, Kunshan Ultrasonic Instrument Co., ltd., Jiangsu, China). The liquid phase was decanted, cooled to room temperature, and centrifuged at 1,789 × g for 15 min to produce the extract. The extraction was repeated using the same protocol for the residual and all the extracts were combined before taken to concentrate using a vacuum evaporator (V-700 Vacuum Pump, Buchi, Bangkok, Thailand).

Total phenolic content (TPC)

TPC was determined following the methods of Singleton and Rossi (1965) with some modifications. All extracted samples (20 μl) were introduced into 96-well plates followed by the addition of 100 μl of 10% Folin–Ciocalteu's reagent (v/v) and incubation in the dark at 30°C for 6 min, followed by the addition of 80 μl Na2CO3 (7.5% w/v) and the mixture was incubated for another 30 min. The absorbance was measured at 765 nm using a microplate reader (Varioskan LUX, Thermo Scientific, Singapore). TPC content was reported as mg gallic acid equivalent/g DW using gallic acid as the standard at a concentration of 50–170 μg/mL (R^2 = 0.999).

DPPH assay

2,2-Diphenyl-1-picryl hydrazyl (DPPH) radical scavenging activity was determined using the method modified from Kanlayavattanakul *et al.* (2012). First, 100 μl of sample extract was mixed with 100 μl 0.2 mM DPPH in 95% ethanol. The sample was incubated in the dark for 30 min at 30°C. The absorbance was measured at 517 nm and reported as μg gallic acid, Trolox acid, and ascorbic acid equivalent/g DW using gallic acid as the standard at a concentration of 0.5–3.5 μg/mL, Trolox acid as the standard at a concentration of 2–4 μg/mL, and ascorbic acid as the standard at a concentration of 20–120 μg/mL (R^2 = 0.9959).

Microbiological analysis

Total viable count

The total viable count (TVC) was analyzed following the method of The United States Food and Drug Administration (2001). The sample and peptone water were mixed in a blender jar and blended at a 10^{-1} dilution before diluting to 10^{-2-6}. Then, 1 mL of each dilution was transferred to a plate and added with 15 mL of plate count agar. The plates were rotated to spread and solidify the agar before inversion and incubation at 35°C for 48 hours. The number of microbials was counted and recorded in colony-forming units per gram (log CFU/g).

Yeast and mold count

Yeasts and molds were analyzed according to the method of The United States Food and Drug Administration (2001).

Briefly, sample in 0.1% peptone water were mixed to make 10^{-1} dilution. The mixture was homogenized and appropriate dilutions were made. One milliliter of each sample dilution was applied onto the plates and Dichloran Rose Bengal Chloramphenicol (DRBC) agar was added. The contents were mixed by gently swirling plates clockwise, then counter clockwise, and then incubated in the dark at 25°C. Incubations containing 10–150 colonies were selected for counting and the number of microbials was recorded as log CFU/g.

Statistical analysis

The experiment was conducted as a randomized complete block design (RCBD). All experiments were performed at least in triplicate, with data presented as mean ± standard deviation. One-way ANOVA in terms of Duncan's test with a significance level of 0.05, PCA, and LDA were performed using SPSS Statistics 22 (SPSS Inc., IBM, NY, USA) software. Origin software (Origin Lab, Northampton, MA, USA) was used for the experimental data.

Results and discussion

Initial pH, moisture content, and a_w of ingredients and formulations

The pH, a_w, and moisture contents of dried shrimp and white and black sesame seeds used in Thai Furikake are shown in Table 3. Generally, dried shrimp had higher values than sesame seeds indicating a shorter shelf life. A higher pH of any sample relates to an increase of basic substances including ammonia and other amine compounds as well as a reduction of acid compounds such as ascorbic acid and other weak acids contained in the food (Osuna-Padilla *et al.*, 2019; Adeva and Souto, 2011). Rababah *et al.* (2017) reported the a_w value of sesame seeds as 0.23. The lower a_w value in this experiment was due to different processes and time intervals. A lower a_w value indicates longer shelf life with reduced microbiological product deterioration.

Table 3. The pH, a_w, and moisture contents of dried shrimp, black and white sesame seeds used in Thai Furikake dried seasoning powder.

Sample	pH	a_w	Moisture (%)
Dried shrimp	7.00 ± 0.05[b]	0.55 ± 0.004[b]	8.41 ± 0.010[c]
Black sesame seeds	6.05 ± 0.01[a]	0.17 ± 0.002[a]	0.86 ± 0.005[b]
White sesame seeds	6.05 ± 0.04[a]	0.17 ± 0.005[a]	0.79 ± 0.008[a]

[a–c] Means within the same row with different letters are significantly different ($p < 0.05$). n = 3, results shown as mean ± standard deviation.

Moisture content and a_w

The moisture content of fresh Liang leaves was 83.13%. However, after addition of seasoning (salt, caster sugar, soy sauce), drying, powdering, and mixing with the other ingredients (dried shrimp and sesame seeds), moisture content ranged from 5.81% to 7.40%, within the FDA regulation. The lowest moisture content was found in the control sample with no added shrimp and sesame seeds. Adding shrimp increased the moisture content. However, the a_w values (Table 4) did not correlate well with moisture contents because of the compositional variation of each mixture formulation as well as temperature fluctuations in the hot air oven may be due to cabinet design problem (Shahapuzi, 2015). Adding salt and sugar reduced a_w values but also made the drying process more difficult due to their water-binding properties. Thus, reducing a_w and/or moisture content took longer and the a_w value was not reduced to the same level as the control (no salt added) (Rahman and Mujumdar, 2007).

All formulations showed a_w values between 0.32 and 0.46, while a_w values for F1–F5 ranged from 0.39 to 0.46 and were higher than the control (0.32) without added dried shrimps and sesame seeds (Table 4). The a_w values of F1–F5 were acceptable according to the FDA Standard (Food and Drug Administration, 2001) at less than 0.6. Strangely, F2 exhibited a higher a_w value than F1. The dried shrimp content increased from F1 to F5; therefore, F5 should have the highest a_w among all the treatments. This may be due to fluctuations in temperature and air ventilation in the hot air oven were high as one

Table 4. Moisture contents and a_w of Thai Furikake dried seasoning powder.

Sample	Moisture (%)	Water activity (a_w)
Fresh leaves	83.13 ± 0.62[c]	0.99 ± 0.001[e]
Control	5.81 ± 0.007[a]	0.32 ± 0.018[a]
F1	6.17 ± 0.010[ab]	0.39 ± 0.004[b]
F2	6.62 ± 0.004[ab]	0.46 ± 0.002[d]
F3	7.10 ± 0.002[ab]	0.42 ± 0.012[c]
F4	7.40 ± 0.003[b]	0.42 ± 0.004[c]
F5	6.98 ± 0.003[ab]	0.41 ± 0.003[bc]

Control: Seasoned Liang leaves powder without dried shrimp and sesame seeds; F1: Seasoned Liang leaves powder, dried shrimp a%, black and white sesame seeds b%; F2: Seasoned Liang leaves powder, dried shrimp (a+1)%, black and white sesame seeds (b-1)%; F3: Seasoned Liang leaves powder, dried shrimp (a+2)%, black and white sesame seeds (b-2)%; F4: Seasoned Liang leaves powder, dried shrimp (a+3)%, black and white sesame seeds (b-3)%; F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4)%.[a–d]Means within the same row with different letters are significantly different ($p < 0.05$). n = 3, results shown as mean ± standard deviation.

of the disadvantages of conventional drying equipment (Shahapuzi, 2015), suggesting that an alternative drying method such as drum dryer should be used. It pointed out that equipment and utensils used can be a key factor affecting experiment results instead which needed to be aware of interpretation.

pH value

When the dried seasoning powder from Liang leaves with mineral fortification and the control were analyzed, pH values ranged from slightly acidic to neutral, with values from 5.54 to 6.36. F5 showed the highest pH ($p < 0.05$). When more dried shrimp was added, the pH increased as F1<F2<F3<F4<F5, as shown in Table 5, attributed to the presence of ammonia during harvesting, handling, boiling, sorting, and drying. Rough handling and poor hygiene impact the freshness of raw shrimp (Ward *et al*., 2020). The standard regulation of dried shrimp states that ammonia content should not exceed 500 ppm for first-class quality (Ministry of Industry, 1990). It meant that the dried shrimp used in this experiment may not be of top good grade because of the costing constraint. Currently, lower quality ingredients are often used in SME and industrialized businesses due to the costing constraint that very much pressure government considerations on how to control product quality and ensure safety improvement and guarantee.

Color

Dried shrimp seasoning from Liang leaves with mineral fortification was dark green with a brown shade, as shown in Figure 1.

Values of L*, a*, and b* ranged from 28.61 to 37.61, –6.57 to –4.70, and 18.81 to 22.71, respectively (Table 5). Mixture formulations with dried shrimp addition exhibited higher a*values compared to the control without dried shrimp because astaxanthin liberated during boiling and drying imparted a reddish-orange color (Rodríguez *et al*., 2017). Adding more dried shrimp to the sample did not significantly affect the a* value. F5, with the highest dried shrimp content, did not significantly differ ($p < 0.05$) in terms of a* value compared to F1 with the lowest amount of dried shrimp because the dried shrimp amount added was not large.

Sensory evaluation

Participants scored Thai Furikake dried seasoning powder made from Liang leaves as rice topping for appearance, color, aroma, and taste with statistically significant differences ($p < 0.05$) but with no significant differences ($p < 0.05$) for the texture attribute. F5 recorded a higher sensory score compared with the control sample (Table 6). A higher score obtained from the addition of dried shrimp and sesame seeds indicated the combined effect of protein and fat leading to improved consumer palatability (Stubbs and Blundell, 2013). Duck sausages with 20% fat content obtained higher scores for sensory preference compared with sausages of 30% and 40% fat content while the higher fat content sample showed improved texture and juiciness attributes (Lorenzo *et al*., 2011). It pointed out that proper ingredients's combination was product dependent. Addition more dried shrimp increased sensory acceptance score compared with sesame seed. Therefore, the F5 formulation was selected to assess quality changes during storage.

Calcium and phosphorus content

Calcium content was almost three times higher in dried shrimp than in sesame seeds. Calcium content in F5 was 9.1 times higher than the control, reaching 4,299.45 mg/kg. Similarly, phosphorus content in F5 was 3.5 times higher at 3,436.32 mg/kg compared to the control without the addition of shrimp and sesame seeds (Table 7). Agahar-Murugkar *et al*. (2018) reported that addition of sesame seeds to cookies increased phosphorus content by 2.1 times compared to the control without added sesame seeds.

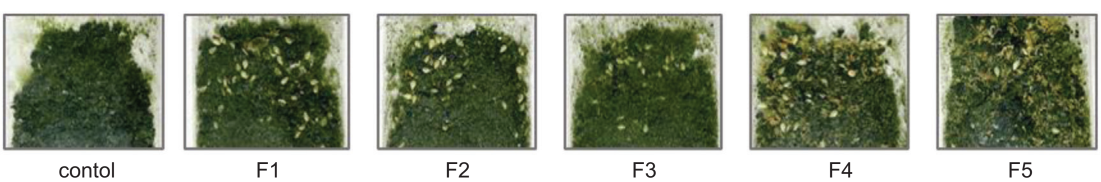

Figure 1. Image of the product formulations. Control: Seasoned Liang leaves powder without dried shrimp and sesame seeds; F1: Seasoned Liang leaves powder, dried shrimp a%, black and white sesame seeds b%; F2: Seasoned Liang leaves powder, dried shrimp (a+1)%, black and white sesame seeds (b-1)%; F3: Seasoned Liang leaves powder, dried shrimp (a+2)%, black and white sesame seeds (b-2)%; F4: Seasoned Liang leaves powder, dried shrimp (a+3)%, black and white sesame seeds (b-3)%; F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4)%

Table 5. L*, a*, and b* and pH values of Thai Furikake dried seasoning powder made from Liang leaves.

Sample	pH	Color		
		L*	a*	b*
Control	5.54 ± 0.02[a]	34.24 ± 0.02[c]	−6.57 ± 0.04[a]	22.71 ± 0.30[c]
F1	5.84 ± 0.03[b]	28.61 ± 0.09[a]	−4.98 ± 0.20[b]	18.97 ± 0.10[a]
F2	6.03 ± 0.02[c]	35.92 ± 0.02[e]	−5.20 ± 0.01[b]	22.59 ± 0.06[c]
F3	6.14 ± 0.06[d]	32.65 ± 0.03[b]	−4.70 ± 0.17[c]	19.69 ± 0.29[b]
F4	6.21 ± 0.01[e]	34.75 ± 0.01[d]	−4.75 ± 0.07[c]	18.81 ± 0.10[a]
F5	6.36 ± 0.06[f]	37.61 ± 0.03[f]	−5.02 ± 0.07[b]	19.89 ± 0.20[b]

Control: Seasoned Liang leaves powder without dried shrimp and sesame seeds; F1: Seasoned Liang leaves powder, dried shrimp a%, black and white sesame seeds b%; F2: Seasoned Liang leaves powder, dried shrimp (a+1)%, black and white sesame seeds (b-1)%; F3: Seasoned Liang leaves powder, dried shrimp (a+2)%, black and white sesame seeds (b-2)%; F4: Seasoned Liang leaves powder, dried shrimp (a+3)%, black and white sesame seeds (b-3)%; F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4)%,
[a–f] Means within the same row with different letters are significantly different ($p < 0.05$). n = 3, results shown as mean ± standard deviation.

Table 6. Sensory evaluation of Thai Furikake rice seasoning powder.

Sample	Sensory attribute					
	Appearance	Color	Flavor	Taste	Texture	Overall liking
Control	5.88 ± 2.18[a]	6.17 ± 2.02[a]	5.87 ± 1.69[a]	6.43 ± 1.66[a]	6.45 ± 1.96[a]	6.23 ± 1.83[a]
F1	6.52 ± 1.16[bc]	6.53 ± 1.22[ab]	6.70 ± 1.76[bc]	6.55 ± 1.48[a]	6.58 ± 1.28[a]	6.72 ± 1.01[bc]
F2	6.07 ± 1.57[ab]	6.45 ± 1.37[ab]	6.30 ± 1.43[abc]	6.53 ± 1.56[a]	6.65 ± 1.16[a]	6.60 ± 1.30[ab]
F3	6.58 ± 1.37[bc]	6.80 ± 1.18[b]	6.68 ± 1.35[bc]	7.07 ± 1.42[c]	6.85 ± 1.10[a]	7.05 ± 1.25[bc]
F4	6.40 ± 1.53[abc]	6.58 ± 1.18[ab]	6.27 ± 1.44[ab]	6.78 ± 1.17[ab]	6.83 ± 1.29[a]	6.68 ± 1.14[bc]
F5	6.73 ± 1.51[c]	6.67 ± 1.28[b]	6.80 ± 1.30[c]	7.10 ± 1.53[c]	6.88 ± 1.34[a]	7.10 ± 1.24[c]

Control: Seasoned Liang leaves powder without dried shrimp and sesame seeds; F1: Seasoned Liang leaves powder, dried shrimp a%, black and white sesame seeds b%; F2: Seasoned Liang leaves powder, dried shrimp (a+1)%, black and white sesame seeds (b-1)%; F3: Seasoned Liang leaves powder, dried shrimp (a+2)%, black and white sesame seeds (b-2)%; F4: Seasoned Liang leaves powder, dried shrimp (a+3)%, black and white sesame seeds (b-3)%; F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4)%,
[a–c] Means within the same row with different letters are significantly different ($p < 0.05$). n = 60, results shown as mean ± standard deviation.

Table 7. Calcium and phosphorus contents in dried shrimp, sesame, and Thai Furikake dried seasoning powder.

Sample	Calcium (mg/kg)	Phosphorus (mg/kg)
Dried shrimp	11,816.09 ± 51.50[c]	8,009.69 ± 25.16[d]
Sesame	4,201.19 ± 26.04[b]	5,064.90 ± 8.40[c]
Control	474.80 ± 2.92[a]	957.34 ± 7.65[a]
F5	4,299.45 ± 18.53[b]	3,436.32 ± 3.48[b]

Control: Seasoned Liang leaves powder without dried shrimp and sesame seeds, F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4)% [a–c] Mean values in the same row with different letters are significantly different ($p < 0.05$). DW = dry weight. n = 3, results shown as mean ± standard deviation.

Chlorophyll and carotenoid contents

Fresh Liang leaves contained 50.14 ± 0.65 mg/g DW (dry weight) total chlorophyll content and 14.76 ± 0.05 mg/g DW carotenoid content. In the control, the chlorophyll content was 11.71 ± 0.03 mg/g DW, with a carotenoid content of 3.82 ± 0.09 mg/g DW. The addition of dried shrimp and sesame seeds in F5 yielded 11.38 ± 0.07 mg/g DW of total chlorophyll content and 3.52 ± 0.03 mg/g DW of carotenoid content (Table 8). No doubt, fresh Liang leaves provided higher contents of chlorophyll and carotenoid compared to rice seasoning powder in both the control and F5 treatments. The lower values of chlorophyll and carotenoid found in the products were due to the drying process and other added ingredients that led to a dilution effect. Chlorophyll is not a stable compound when exposed to heat, acid, enzyme, and light (Li *et al.*, 2018) and is converted into pheophytin, resulting in a change in color from green to brownish green. Erge *et al.* (2008) observed that chlorophyll a and b in green beans underwent degradation and reduction in quantity when subjected to temperatures ranging from 70 to 100°C. Chlorophyll a degraded faster compared to chlorophyll b by 12–18 times depending on the temperature because chlorophyll a is more heat-sensitive than chlorophyll b.

Table 8. Chlorophyll and carotenoid contents (mg/g DW) in fresh Liang leaves and Thai Furikake dried seasoning powder with and without added natural minerals (F5 and the control).

Sample	Chlorophyll (mg/g DW)		Carotenoid (mg/g DW)	
	Chlorophyll A	Chlorophyll B	Total chlorophyll	Carotenoid
Fresh	17.23 ± 0.11[b]	32.93 ± 0.75[b]	50.14 ± 0.65[b]	14.76 ± 0.05[c]
Control	3.30 ± 0.01[a]	8.42 ± 0.01[a]	11.71 ± 0.03[a]	3.82 ± 0.09[b]
F5	3.28 ± 0.01[a]	8.11 ± 0.01[a]	11.38 ± 0.07[a]	3.52 ± 0.03[a]

Control: Seasoned Liang leaves powder without dried shrimp and sesame seeds, F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4)%
[a–c] Mean values in the same row with different letters are significantly different ($p < 0.05$). DW = dry weight. n = 3, results shown as mean ± standard deviation.

D'Evoli *et al.* (2013) studied how heat impacted carotenoid content in cherry tomatoes. They found that beta-carotene in tomatoes decreased from 1.00 ± 0.05 mg/100g FW to 0.75 ± 0.05 mg/100g FW after heat treatment at 100°C.

Total phenolic content

Fresh leaves had the highest phenolic content of 13,836.84 ± 412.14 µg GAE/g DW, with the control sample and F5 exhibiting TPC values of 3,300.16 ± 176.16 µg GAE/g DW and 2,575.28 ± 103.80 µg GAE/g DW, respectively (Fig. 2 (a)). The lowest TPC in F5 was due to heat treatment during processing and the dilution effect from other added ingredients. The F5 formulation contained lower TPC compared to the control because of the reduced proportion of Liang leaves. Niamnuy *et al.* (2012) studied the impact of drying temperature on the TPC of lotus leaves and reported that at 50°C resulted in a higher TPC value compared to drying it at 60°C and 70°C. TPC decreased as drying temperature increased due to heat-induced degradation of phenolic acids that changed to other components containing fewer functional groups.

DPPH assay

The drying process reduced the ability to inhibit free radicals, therefore, the ability to scavenge DPPH radicals decreased when Liang leaves underwent heat treatment (Fig. 2(b)), concurring with Niamnuy *et al.* (2013). Changes in the ability to scavenge free radicals correlated with the quantity of bioactive compounds, particularly TPC, as the main bioactive substances in Liang leaves were involved in the inhibition of free radicals. The more amount of Liang leaves the less total phenolics and antioxidant activity determined by DPPH assay because of the dilution effect. In addition, the lowest value of using gallic acid as standard was noticed when compared with ascorbic and Trolox because of highest functional groups, OHs containing in the molecule instead of using the previous one.

Quality changes during storage of selected Thai Furikake dried seasoning powder

The selected product (F5) was taken to store in laminated packaging at 25 and 60°C with relative humidity of 60% and 90% for 30 days, thereafter, physical and microbial quality were randomly evaluated every 7 days and the result showed as following details.

Moisture content and a_w value

Moisture content and a_w value of the selected Thai Furikake product (F5) seemed to increase with storage time at 40°C and relative humidity of 90%. However, there was not much change in pH in all samples with 6.36–6.45. The product kept at lower relative humidity showed lower moisture contents and a_w values than the product stored at higher relative humidity, while increases in moisture contents and a_w values of the product kept at lower temperatures (25–27°C) were lower compared with the product stored at 40–42°C. Thus, temperature may play a key role in relative humidity and the product should be kept in proper containers with laminated material. Storage for 7 days reduced both moisture content and a_w in all treatments before increasing. Reduction of moisture content and a_w during the first 7 days may be due to the void volume in the package. Changes in moisture contents and a_w values of the product during the first 7 days of storage differed because of the heterogeneous nature of the raw materials and varying utensil usage and environmental conditions. The a_w values increased as storage time increased in all treatments, while moisture content reduced before rising as storage time increased. Although the a_w values of the product kept for 30 days were still acceptable for the dried food category (a_w<0.6), increasing of a_w (>0.35) indicates the not-too-crispy or crunchy characteristic (Jakubczyk *et al.*, 2008). Awulachew (2021) found that the product with low moisture content and/or low a_w tended to experience increased moisture content when stored in high relative humidity environments and suggested that a_w may be

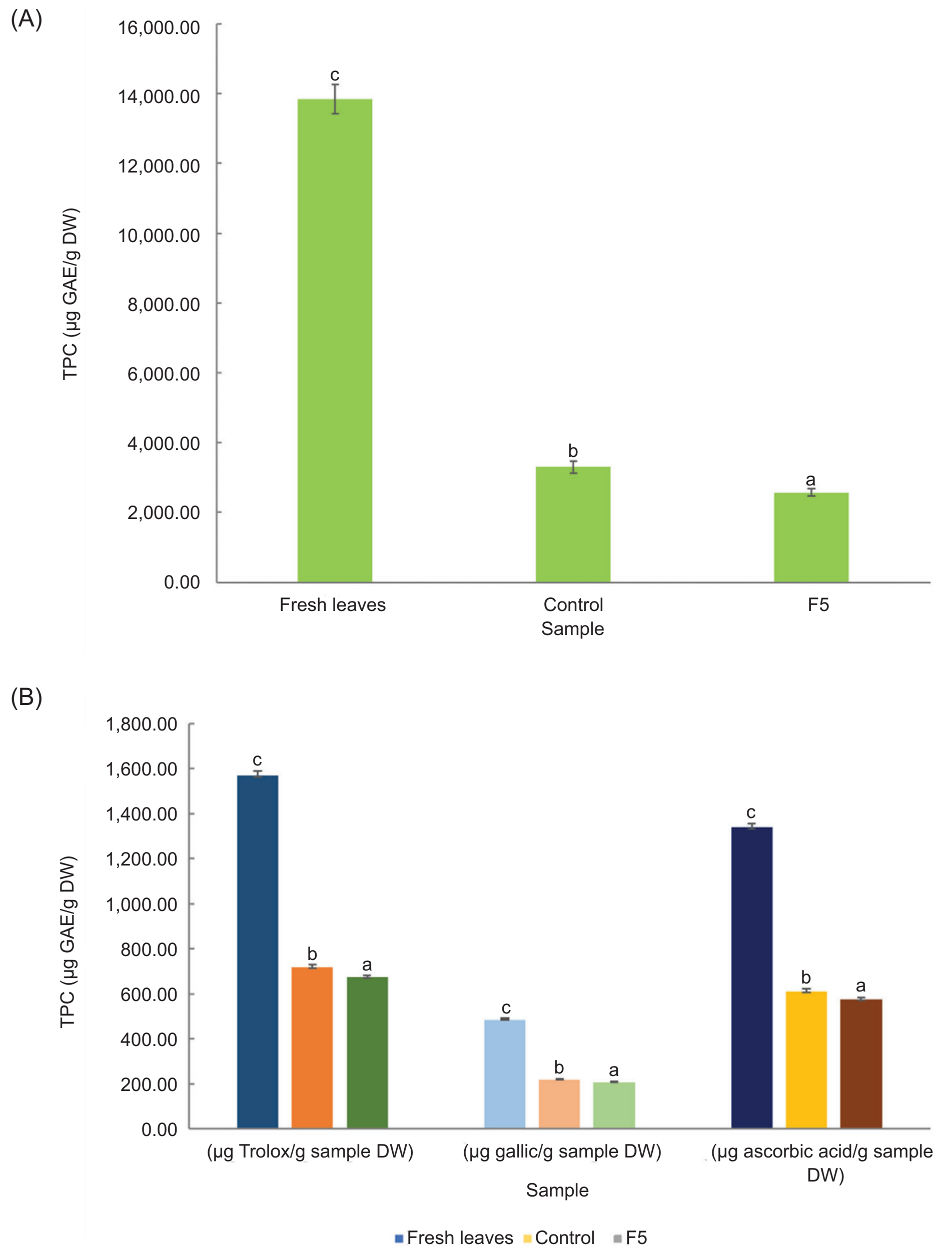

Figure 2. **(A) Total phenolic content of fresh leaves and Thai Furikake dried seasoning powder and (B) antioxidant activity of fresh leaves and Thai Furikake dried seasoning powder. Control: Seasoned Liang leaves powder without dried shrimp and sesame seeds, F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4) %, [a–c] Mean values in the same row with different letters are significantly different ($p < 0.05$). DW = dry weight. n = 3, results shown as mean ± standard deviation.**

a better parameter to indicate dried product quality than moisture content (Fig. 3).

Color

The L* values of the product stored at 25°C for 21 days were similar to the initial values ($p < 0.05$) (Table 9) but differed significantly when compared to the 30-day storage, while the L*values of the product kept at 40°C exhibited significant difference ($p < 0.05$), with a decrease in L* observed after storing for 30 days. Storing at a lower temperature (25°C) and relative humidity (60%) retained color quality better than at 40°C and 90% RH. Singh and Sugar (2010) reported that products stored at room temperatures (15–35°C) exhibited significant color change compared to those stored at lower temperatures because increased moisture absorption enhanced the interaction between sugar and

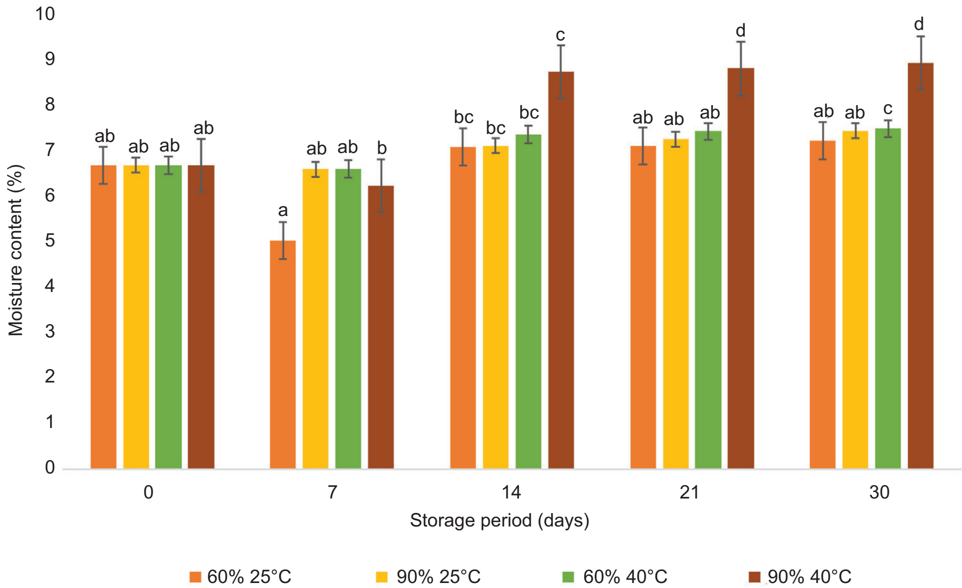

Figure 3. **Changes in moisture content of Thai Furikake rice seasoning during storage at 25–27°C and 40°C with relative humidity levels of 60% and 90%. F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4) %, [a–d] Mean values in the same row with different letters are significantly different ($p < 0.05$). n = 3, results shown as mean ± standard deviation.**

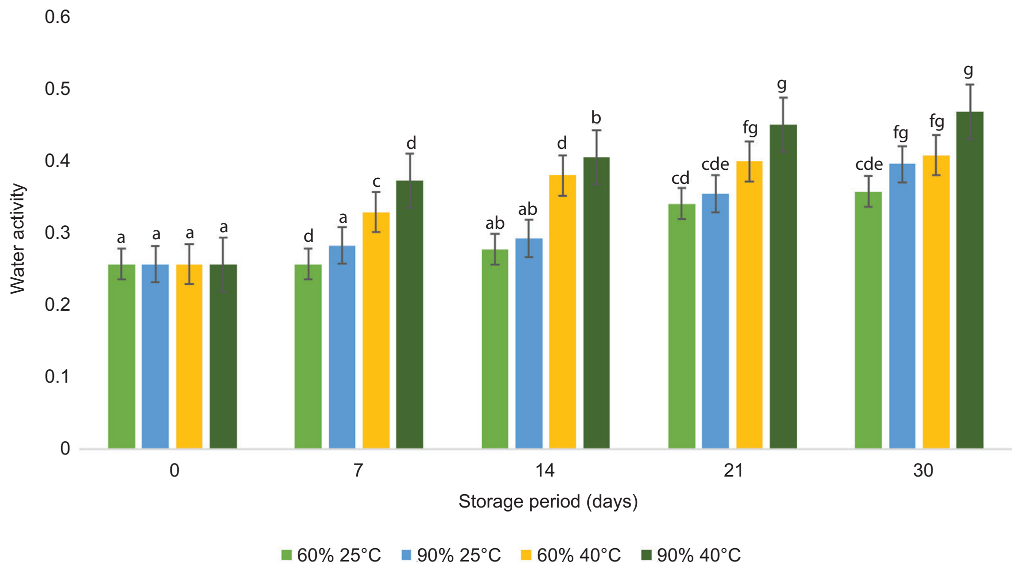

Figure 4. **Changes in a_w of Thai Furikake rice seasoning powder during storage at 25–27°C and 40°C with relative humidity levels of 60% and 90%. F5: Seasoned Liang leaves powder, dried shrimp (a+4)%, black and white sesame seeds (b-4) %, [a–d] Mean values in the same row with different letters are significantly different ($p < 0.05$). n = 3, results shown as mean ± standard deviation.**

amide compounds in seasoning and food ingredients. The a* value significantly decreased in all conditions as storage time increased (Table 9), while the b* values of the product kept for 14 days differed from initial values before storage.

Microbiological analysis

The TVC in the stored product ranged from 4.67 to 9.30 × 10^5 CFU/g (Table 10). The initial microbiological quality of the product was higher than after storage at 25°C for 7 days, suggesting that the main microorganisms were mesophiles, with the lower temperature inducing higher cell injury as a function of the heat–cold shock phenomenon before entering the death phase. However, the TVC of products kept at higher temperatures and relative humidity increased with storage time. Hyun *et al.* (2017) reported that dried vegetables stored at 90% relative humidity and 35°C had greater microbial numbers compared to products stored at 25°C after

Table 9. Color of Thai Furikake rice seasoning powder during storage at 25–27°C and 40°C with relative humidity levels of 60% and 90%.

Day	Temperature (°C)	%RH	Color		
			L*	a*	b*
0	-	-	40.73 ± 0.02^{g}	−4.17 ± 0.05^{ab}	24.76 ± 0.12^{f}
7	25	60	40.25 ± 0.01^{g}	−4.29 ± 0.14^{a}	24.15 ± 0.78^{cdef}
		90	37.10 ± 0.02^{e}	−4.24 ± 0.19^{a}	24.04 ± 0.26^{bcdef}
	40	60	40.29 ± 0.04^{g}	−4.27 ± 0.28^{a}	24.52 ± 0.41^{ef}
		90	36.76 ± 0.02^{e}	−3.88 ± 0.12^{bcd}	24.08 ± 0.37^{cdef}
14	25	60	39.18 ± 0.02^{f}	−3.50 ± 0.04^{e}	24.51 ± 0.05^{ef}
		90	36.64 ± 0.03^{e}	−3.77 ± 0.06^{cde}	24.38 ± 0.09^{def}
	40	60	37.18 ± 0.02^{e}	−3.66 ± 0.05^{de}	24.39 ± 0.12^{def}
		90	35.79 ± 0.00^{d}	−4.05 ± 0.08^{abc}	24.16 ± 0.05^{cdef}
21	25	60	39.08 ± 0.52^{f}	−3.44 ± 0.24^{e}	23.82 ± 0.15^{bcde}
		90	36.70 ± 0.57^{e}	−3.68 ± 0.27^{de}	23.35 ± 0.94^{bc}
	40	60	37.20 ± 0.19^{e}	−3.47 ± 0.71^{e}	24.13 ± 0.21^{cdef}
		90	35.81 ± 0.65^{d}	−3.62 ± 0.10^{de}	23.54 ± 0.36^{bcd}
30	25	60	33.83 ± 0.46^{c}	−3.00 ± 0.27^{f}	23.31 ± 0.48^{bc}
		90	32.22 ± 0.53^{b}	−2.29 ± 0.04^{g}	23.18 ± 0.92^{b}
	40	60	31.82 ± 0.89^{b}	−1.11 ± 0.04^{h}	23.17 ± 0.64^{b}
		90	30.93 ± 0.04^{a}	−1.0 ± 0.07^{h}	22.10 ± 0.11^{a}

$^{a–h}$ Means within the same row with different letters are significantly different ($p < 0.05$). RH = Relative humidity. n = 3, results shown as mean ± standard deviation.

Table 10. Microbiological qualities of Thai Furikake rice seasoning powder.

Day	Temperature (°C)	%RH	Microbiological quality (CFU/g)	
			TVC	Yeast/mold
0			8.55 × 105 ± 2.12	4.33 × 103 ± 3.05
7	25	60	4.67 × 105 ± 1.53	4.67 × 103 ±1.73
		90	7.63 × 105 ± 1.52	5.33 × 103 ± 5.33
	40	60	6.80 × 105 ± 2.82	5.00 × 103 ± 2.08
		90	8.30 × 105 ±1.41	6.00 × 103 ± 1.00
14	25	60	5.00 × 105 ± 4.24	ND
		90	7.30 × 105 ± 8.49	ND
	40	60	7.15 × 105 ± 9.19	ND
		90	8.80 × 105 ± 1.41	ND
21	25	60	5.03 × 105 ± 7.02	4.33 × 103 ± 2.52
		90	7.27 × 105 ± 7.23	6.50 × 103 ± 2.12
	40	60	7.37 × 105 ± 8.08	5.67 × 103 ± 0.58
		90	8.97 × 105 ± 2.08	6.33 × 103 ± 1.53
30	25	60	5.66 × 105 ± 7.52	6.66 × 103 ± 0.57
		90	7.20 × 105 ± 13.53	7.32 × 103 ± 2.09
	40	60	7.33 × 105 ± 9.02	8.34 × 103 ± 2.51
		90	9.30 × 105 ± 8.54	8.67 × 103 ± 1.52

ND = not determined, RH = Relative humidity. n = 3, results shown as mean ± standard deviation.

5 days, suggesting that higher temperatures supported a favorable environment for mesophilic microbial proliferation. Yeast and mold ranged between 4.33 and 8.67 × 10^3 CFU/g. The Y/M ratio increased as storage time increased, with both higher temperature and/or relative humidity enhancing yeast and mold growth,

indicating that these factors played a role in microbial growth or inhibition. Overview of microorganism quality in this experiment indicated that there were various risk factors for safety. Hot air oven with temperature around 50–70°C is not high enough to reduce or kill mesophilic spore-forming bacteria and fungi. Since ready-to-eat products are required to pass microbiological standard as TVC (<10^6 CFU/g), yeast and mold (<100 CFU/g), indicating that the product was not good for consumption because of containing high mold and yeast counts. The microbiological problem in this experiment may be due to the constraint of work area and equipment using in various purposes such as teaching, demonstrating, and consulting which differed from the cleaned room in the industry plant. In addition, using hot air over with temperature around 60°C, may not high enough to kill the germs and unwell cleaned areas and utensils in this experiment may turn out to a source or shelter of microorganism. However, all weak points finding in this experiment can be delivered to SME and entrepreneurs whether how environment affect the product quality and safety? And how to manage with care? For example, using drum dryer and flaming technique may be other options to microbial reduction because of contact with high temperature. In addition, washing process for the raw material should be changed with the use of efficacy solution or techniques such as weak acid solution (vinegar), alkaline solution (H_2O_2), blanching, etc., (Siripongvutikorn *et al*., 2023).

Conclusions

Thai Furikake rice seasoning powder made from Liang leaves fortified with dried shrimp and sesame seeds was processed by hot air drying with moisture content and a_w values of 5.81 ± 0.007 and 7.40 $\pm$ 0.003, respectively. The addition of dried shrimp and sesame seeds significantly improved consumer acceptability, calcium, and phosphorus content. The F5 formulation provided a total phenolic content of 2,575.28 ± 103.80 µg GAE/g DW with DPPH antioxidant activity of 676.99 ± 6.29 Trolox/g sample DW. Keeping the product at lower temperature (25–27°C) and relative humidity (60%) retained higher quality parameters compared with higher temperature (40–42°C) and relative humidity (90%). As storage time increased, product quality decreased. Yeast and mold count was quite high (>100 CFU/g) and not safe for consumption therefore, elimination or reduction is needed to further study.

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