Effects of Sterilization on the Physicochemical Properties of Ready-to-eat Fried Rice with Traditional Golek Sauce in Retort Bowl

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Abstract
Ready-to-eat fried rice with Golek sauce, a traditional food product of Southern Thailand, was developed using a standard recipe. The product, which was sterilized in a retort bowl at 116°C and an F0 value of 5 min, exhibited a slightly decreased L* value, increased a* and b* values, and a trend for an increasing pH. While the protein and carbohydrate content decreased, the fat, ash, moisture content and water activity index all increased. The sterilization process decreased the hardness, cohesiveness, and chewiness of the cooked rice, a main component of the product, whereas the texture parameters of the cooked vegetable protein (TVP) increased. The product exhibited acceptable sensory quality characteristics, and no living microorganisms were detected in the product after 6 months of storage at ambient temperature. These findings indicate that the retort sterilization process does not negatively affect the quality of this food product to a degree that is unacceptable. The viability and manufacturability of a ready-to-eat fried rice with traditional Golek sauce should provide consumers an additional choice of a safe, convenient, and delicious southern food that may be a favorite of many people.

Keywords: Golek sauce, ready-to-eat, retort, processing food, physicochemical properties

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1. Introduction

In the southern region of Thailand, Golek sauce is widely used to marinate chicken that has been traditionally cooked slowly over an open fire. The main ingredients of the sauce include chopped and blended red chilies, red onions, some spices, seasonings and coconut milk. These ingredients are mixed (stirred) together and fried in a wok until the sauce attains a sticky consistency; producing a sauce with a spicy and sweet taste, which is perfumed with the aroma of the spices. Despite its popularity, Golek marinated chicken has a relatively long preparation time and is not always easily accessible outside of southern Thailand. However, Golek sauce may also be used with other foods to meet the taste requirements of the consumer. Since rice is a staple food that is consumed on a daily basis in Thailand and across the whole of Asia, the addition of Golek sauce in the form of a ready-to-eat rice meal, may offer a popular alternative to meet consumer demand.

The development of shelf-stable sauce using heat sterilization should be developed in order to commercially distribute this uniquely local culinary treat in Thailand and other export markets. Traditional food sterilization and storage processes, on the other hand, often result in a decrease in the perceived freshness and consistency of the finished product. This problem can be achieved using retort processing technology, which is one of the thermal processing techniques. Retort technology has been widely recognized as an alternative to the flexible laminate bowl and conventional sterilization techniques. It involves a commercial sterilization process were a heat treatment in the range of 112-125°C is applied for 8-10 min to sterilize low acid foods (pH>4.6 and a0>0.85), such as rice. This process inactivates all microbials and their spores, including the most-difficult-to-completely-sterilize Clostridium botulinum, Bacillus stearothermophilus [1]. The complete sterilization of the product, ensures that it is safe for consumption and stable on the shelf for up 12 months [2].

There are several types of retort such as stream retort, water retort, water spray retort, total immersion in water, reel and spiral retort, stream-air mixer retort, crateless retort and hydrostatic retort [3]. During retort processing, there may be an appreciable loss in desired physical and chemical properties, such as the texture of rice. For example, Retort processing of soy protein isolate tofu caused an increase in its hardness and texture profiles with...
a decrease in moistness and overall acceptability [4]. In a previous study, Gaeng Phed Gai was heat-treated to an F0 value of 10 min at 121°C, causing a slight increase in pH due to the splitting of protein hydrogen bonds releasing positive hydrogen ions [5]. This led to comments about the flavor of the spices being lost during the heat treatment, thus the loss of flavor was compensated by adding more spices before the heating process. The loss of flavor may have been due to the heat treatment effecting the proximate content of the food and triggering the Maillard reaction [6]. A previous study demonstrated that the application of 116°C heat (with an F0 value of 5 min) provided optimal conditions for treating fried rice (with shrimp) [7]. The stability of the fried rice was maintained when kept at 25, 35 and 45°C for at least 3 months, with the consumer describing as ‘liking it slightly’ to ‘liking it very much’. In previous research, it was applying comparable commercial sterilizing conditions (121°C with an F0 value of 5 min) to four different Thai foods (Moo-Kra-tium, Pa-nang, Gaeng-Phed, and Gaeng-jued) resulted in the foods becoming free of microorganisms while still possessing acceptable sensory qualities [8].

The aim of this study was to investigate the effects of water spray retort sterilization on the physicochemical properties of ready-to-eat fried rice with Golek sauce in a retort bowl. The process factors that affected the qualities of the fried rice with Golek sauce product were studied. The changes in physicochemical properties during the product preparation process were also investigated in order to understand their roles in relation to the product’s overall quality.

2. Materials and Methods

2.1. Materials and Chemicals

The basic ingredients for preparing the fried rice with Golek sauce were bought from a supermarket in Thailand. All chemicals (analytical grade) used in this study were purchased from Sigma Aldrich Company.

2.2. Preparation of Fried Rice with Golek Sauce

The production of fried rice with Golek sauce in the retort bowl are presented in Figure 1. There were three recipes of Golek sauce, which each had the same ingredients except for the addition of jasmine rice and black glutinous rice in recipes number 2 and 3, respectively. The recipe was prepared according to the modified method [9]. Briefly, dried red pepper, dried red chilies, jasmine rice, and black glutinous rice were soaked in water for 1 hour to let them soften. All ingredients were chopped, mixed and blended. The mixed ingredients were stirred and fried in a wok for 15-20 min and cooked for 5 min. The optimized ingredients are provided in Table 1.

Figure 1. Flow diagram for preparation of the retort processed fried rice with Golek sauce
Khao Tah Haeng raw rice from a supermarket in Thailand was soaked (rice/water ratio of 1:2) at 30°C and drained. The sample was boiled in hot water (100°C) for 8 min and the cooked rice was packed into plastic bags [1]. The Golek sauce was then fried with the cooked rice at a ratio of 1:1 for 30 min.

Textured vegetable proteins (TVP) from a local market in Thailand, with a moisture content ≥ 50.43%, were cut into a size of 20 x 20 x 1.3 mm. The Golek sauce was fried with the prepared TVP at a ratio of 1:1 for 30 min [9].

### 2.3. Retort Processing

Retort processing was performed using a Horizontal Steam Retort from Siri Fine foods Co. Ltd. (Suphanburi province, Thailand). A total of 190 g of the product (155 g cooked rice with Golek sauce and 35 g prepared TVP with Golek sauce) was manually filled into a retort bowl (103 x 55 mm (Ø x height) plastic cup). The air was removed from the prepared samples using a steam exhaustor at approx. 100°C for 7 min. The filled and sealed retort bowls were then subjected to the retort processing. A flexible type T thermocouple was connected to a 32-channel CALPlexTM data longer (TechniCal, Inc., USA) via type T extension wire (Ecklund Harrison Technologies, USA,) and inserted into the retort bowl at the cold point of the product. The temperature data was collected every 15 seconds and evaluated using CAL Soft 5 thermal process software, using the Ball formula heating factors. The retort process parameters are shown in Table 2. The process temperature was kept constant at 116°C and the process time was varied. Overpressure was maintained at 1.7 bar. The processed retort bowls were stored in a dry place under an ambient temperature (35 ± 2°C) and the samples were taken for further analysis.

### 2.4. Color Values

The color of the fried rice with Golek sauce was determined using a Minolta CR 300, a compact tristimulus color analyzer used for measuring the reflective colors of surfaces. The color was expressed in L*a*b*, where the L* value represents lightness, the a* value represents redness (+) or greenness (-), and the b* value represents yellowness (+) or blueness (-). The color differences between the sample and standard (white background) were calculated using the resulting colorimetric values [10].

### 2.5. Water Activity (a_w Value)

The water activity of the fried rice with Golek sauce samples were measured using a water activity meter (an AquaLab Series 3), as per [10].

### 2.6. pH

The pH value of the sample was determined according to the method [10]. The samples were homogenized with distilled water at a ratio of 1:10 (w/v). The pH was measured at ambient temperature by using a pH meter (Mettler Toledo Seven GO Pro).

### 2.7. Proximate Composition of Fried Rice with Golek Sauce

The fried rice with Golek sauce was analyzed for moisture content, crude protein, crude fat and total ash, as per standard procedures [10]. The carbohydrate content was calculated by subtracting the percentage of moisture, crude protein, crude fat, and total ash from 100.

### 2.8. Crude Extracts Preparation

A 50 g of the sample was extracted using 250 mL of 80% ethanol. The sample mixture was shaken at room temperature for 30 min and then filtered by Whatman No.1 filter paper. The filtrate was evaporated using a rotary evaporator at 40°C as described [11]. All crude extracts were stored at 4°C in the dark. The extraction of every sample was conducted in triplicate.

### 2.9. Total Phenolic Content (TPC)

TPC was measured using a Folin-Ciocalteu assay according to the method [12]. A 200 µL dilution of crude extracts was added to 1.5 mL of freshly made Folin-Ciocalteu reagent. Then, 1.5 mL of sodium carbonate was added, mixed, and incubated at room temperature for 2 hours. The sample mixture was measured at 725 nm using a UV-VIS spectrophotometer (Thermo Scientific GENESYS 10S Series, Germany). Gallic acid was used as the standard in the range of 0-100 µg·L⁻¹ for the calibration curve. The total phenolic content was expressed as mg gallic acid equivalents (GAE) per gram of sample (mg per 100 g dry weight of sample). All determinations were performed in triplicate.

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Table 1. Ingredients in the Golek sauce

| Ingredients (%) | Recipes |
|-----------------|---------|
|                 | 1       | 2       | 3       |
| Coconut milk    | 58.4    | 58.4    | 58.4    |
| Sugar           | 15      | 15      | 15      |
| Jasmine rice    | 0       | 6       | 0       |
| Black glutinous rice | 0   | 0       | 6       |
| Red onion       | 5.84    | 5.84    | 5.84    |
| Peanut          | 3.5     | 3.5     | 3.5     |
| Water           | 9.42    | 3.42    | 3.42    |
| Dried red pepper| 2.92    | 2.92    | 2.92    |
| Dried red chili | 2.92    | 2.92    | 2.92    |
| Salts           | 1       | 1       | 1       |
| Spices          | 1       | 1       | 1       |
| Net (%)         | 100     | 100     | 100     |

Table 2. The retort processing parameters of the fried rice with Golek sauce product in the retort bowl

| Parameters                | Details |
|---------------------------|---------|
| Retort temperature (°C)   | 116     |
| Initial temperature (°C)  | 35      |
| Come Up Time (CUT) (min)  | 15      |
| Pressure (bars)           | 1.70    |
| Heating lag factor (jh)   | 1.39    |
| Heating rate index (fh) (min) | 38.26 |
| Process lethality (F0)    | 5.0     |
| Process time (min)        | 66      |

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2.10. Total Flavonoid Content (TFC)

Total flavonoid content was determined using the aluminum colorimetric method with slight modification [13]. A 0.5 mL sample of crude extract was mixed to 2 mL of distilled water and then 0.15 mL of 5% of sodium nitrite. The sample mixture was allowed to stand for 5 min before adding 0.15 mL of 10% of aluminum chloride, followed by 1 mL of 4% sodium hydroxide. The sample mixture was mixed and incubated at room temperature for 15 min. The absorbance of pink color, which indicates the presence of flavonoid, was measured at 515 nm using a UV-VIS spectrophotometer (Thermo Scientific GENESYS 10S Series, Germany). Quercetin was used as the standard in the range of 0.02-0.5 mg· mL⁻¹ for the calibration curve. Total flavonoid content was expressed as mg quercetin per 100 g of sample. All determinations were performed in triplicate.

2.11. DPPH Assay

A DPPH radical scavenging activity assay was performed according to the method [12]. A 3.8 mL of 60 µM of 2,2-diphenyl-1-picrylhydrazyl (DPPH) solution (freshly prepared) was added to 200 µL of crude extract. The sample mixture was vortexed and allowed to stand at room temperature for 60 min. The absorption of the sample was measured at 515 nm using a UV-VIS spectrophotometer (Thermo Scientific GENESYS 10S Series, Germany). The DPPH values of the samples were determined according to a standard curve of Trolox solution. The inhibitory percentage of DPPH was calculated according to the following formula:

\[
\text{Scavenging activity(\%)} = \left(\frac{A0 - A1}{A0}\right) \times 100 \quad (1)
\]

Where A0 = the absorbance of the control and A1 is the absorbance of sample extract

2.12. FRAP Assay

The FRAP assay was used with modifications by the method [14]. The FRAP reagent contained 5 mL of 10 mM TPTZ (2,4,6-tripyridyl-S-triazine), which was mixed in a solution of 40 mM HCl, 5 mL of 20 mM FeCl₃, and 50 mL of 300 mM acetate buffer (pH 3.6), at 37°C. A 1.5 mL of FRAP reagent was then mixed with aliquots of the sample supernatant (50 µL) and incubated at 37°C for 10 min. The reaction mixture was measured spectrophotometrically at 593 nm. Using the FRAP working solution as a blank, FeSO₄·7H₂O was used as the standard in the range of 0.1-1 mM for the calibration curve. The values were expressed as the concentration of antioxidants having a ferric reducing ability equivalent to that of 1 mM FeSO₄. All determinations were performed in triplicate.

2.13. Texture Analysis

A texture analyzer (TA-XT2, Texture Technologies Corp., UK) with a 5 kg load cell using a two-cycle compression method via texture profile analysis (TPA) was performed in this study. The cooked rice using a strainer and compressed with pre-test and post-test speeds of 0.5 mm/s and a test speed of 5 mm/s⁻¹ using a 20-mm diameter probe. A two-cycle compression force versus time program was used to compress the samples to 90% of their original thickness, after which the probe returned to its original position before performing the second compression cycle. The results, including hardness, cohesiveness, and chewiness, were determined from the first test curve, and expressed in newtons (N) [15].

2.14. Microbiological Analysis

The fried rice with Golek sauce was analyzed for its commercial sterility. The product was incubated at 35 and 55°C for 7 days [16], with the sulfide spoilage determined in conformity with [17]. Flat sour mesophile, flat sour thermophile, mesophilic anaerobe and thermophilic anaerobe, were estimated according to [18]. A previously as described [19], *Clostridium botulinum* was identified using a standard APHA 2001 procedure.

2.15. Sensory Test

The Golek sauce was evaluated by 30 panelists, and the fried rice with Golek sauces were evaluated by 100 panelists. The sample was coded and given to each panelist in a random order. The panelists were asked to evaluate the appearance, color, odor, texture, taste and overall acceptability of the samples using a 9-point hedonic scale [20]. The scale points were: 1; dislike extremely, 2; dislike very much, 3; dislike moderately, 4; dislike slightly, 5; neither like nor dislike, 6; like slightly, 7; like moderately, 8; like very much and 9; like extremely. Drinking water was provided for cleaning the palate after testing each sample.

2.16. Statistical Analysis

The entire experiment was performed in triplicate. The results were reported as mean± standard deviation (SD). Data of selection of the recipe for Golek sauce preparation were statistically analyzed using one-way analysis of variance (ANOVA) and Tukey’s HSD test (confidence level of 95%). Difference between means of the effect of retort processing on fried rice with Golek sauce were tested by paired sample t test. Statistically significant level was determined as p<0.05 in all analyzes.

3. Results and Discussion

3.1. Selection of the Recipe for Golek Sauce Preparation

The results of the total phenolic contents of the three recipes are presented in Table 3. Recipe number 3 containing the black glutinous rice ingredients showed higher TPC and TFC values (1210.84 mg·100 g⁻¹ dry weight and 932.94 mg·100 g⁻¹ dry weight before retort processing and 1273.97 mg·100 g⁻¹ dry weight and 1007.59 mg·100 g⁻¹ dry weight after retort processing, respectively) compared with recipe number 2, which contained the jasmine rice ingredients (859.61 mg·100 g⁻¹ dry weight and 785.61 mg·100 g⁻¹ dry weight before retort processing and 911.20 mg·100 g⁻¹ dry weight and 847.56 mg·100 g⁻¹ dry weight after retort processing, respectively).
respectively), and recipe 1, which contained the basic formula (375.70 mg·100 g⁻¹ dry weight and 137.81 mg·100 g⁻¹ dry weight before retort processing and 398.49 mg·100 g⁻¹ dry weight and 149.14 mg·100 g⁻¹ dry weight after retort processing, respectively). Similar results were observed for the FRAP values, with recipe 3 having a higher FRAP value (15.65 and 16.75 mg·100 g⁻¹ dry weight before and after retort processing, respectively) compared to recipe 2 (12.01 and 12.85 mg·100 g⁻¹ dry weight before and after retort processing, respectively) and 1 (9.43 and 10.10 mg·100 g⁻¹ dry weight before and after retort processing, respectively). The IC50 of all the samples were negatively correlated with the TPC, TFC, and FRAP values. The IC50 values in recipe 3 (36.13 and 39.01 mg·mL⁻¹ before and after retort processing, respectively) were lower than recipe 2 (79.46 and 85.92 mg·mL⁻¹ before and after retort processing, respectively) and 1 (85.70 and 92.52 mg·mL⁻¹ before and after retort processing, respectively). In our study, it was observed that the ingredients in black glutinous rice may contribute as an antioxidant in Golek sauce. A previous study showed that the black glutinous rice dessert, Koowianodam piak phueak dessert, contained antioxidants. Anthocyanin, the bioactive compound in the black glutinous rice, was determined from cyanidin and cyanidin-3-glucoside [21]. It was indicated that the antioxidant activity and total phenolic contents of black glutinous rice extracts were higher compared with Hom Nil rice extracts [22]. In another report, a greater TPC, TFC, tannin content, MAC (monomeric anthocyanin content), cyanidin-3-glucoside, and peonidin-3-glucoside, were detected in non-waxy rice rather compared with waxy rice [23]. In addition, the dried red pepper, dried red chili, and spice ingredients in Golek sauce, contribute a bioactive source. The red pepper contains a higher level of β-carotene, capsanthin, quercetin, and luteolin and has a higher total phenolic content compared with green peppers [24]. The red pepper pericarp and seed extract were highly effective in scavenging free radicals, likely due to the high phenolic and flavonoid compounds [25].

The effects of retort processing on the TPC, TFC, IC50, and FRAP values in all recipes are shown in Table 3. All antioxidants of three recipes were significantly (P<0.05) increased after retort processing. This may be due to the damage of plant cell walls during retort processing, which cause TPC to be released more than in several herbs and spices. A previous study showed that the Thai red curry paste was subjected to heat treatment by retort at different temperatures (60, 75, 90, 105, and 120°C) and for different times (0, 10, 20, 30, 40, 50, and 60 min). Its result showed that heat treatment by retort increased the TPC and antioxidant activity of all samples [14]. Other research indicated that these compounds can be generated by hydrolysis reaction and condensation during heat treatment. These findings are in agreement result with a previous study, which reported spicy Thai food in retort pouch were heated at 120°C for 15, 25, and 30 min. The antioxidant capacity in Khao Sui Nuea, Khua Kling Mu, Mee Kathi sauce, and Mu Phat Phrik Khing was increased by amounts 3-113%. For the phenolic content was increased in all products by amounts 4-52%. Including, chromatograms of Khao Sui Nuea, Phat Khimao sauce, and Khua Kling Mu by HPLC analysis agreed with the results for the TPC [11].

The sensory evaluation of the three Golek sauce recipes are shown in Table 4. In recipe 1, (without the rice ingredient), there was no significant difference in any parameter compared with recipe 2, which contained jasmine rice. Alternatively, in recipe 3, which contained the black glutinous rice ingredient, there was a significant difference in appearance and color compared with the other recipes (Figure 2). The black glutinous rice is naturally colored dark purple (almost black) and possesses a red and black-violet pigment that is naturally synthesized in the anthocyanin pigment [26]. Despite black glutinous rice having the highest total phenolic and flavonoid content, a common comment was that recipe 3 was not particularly appetizing. This was confirmed by the panelists providing the lowest scores for the overall acceptability of the recipe. While Golek sauce as mixture of jasmine rice (recipe 2) was scored the highest for overall acceptability, appearance, and color compared with recipe 1. Therefore, the recipe 2 was used for developing the ready-to-eat fried rice with Golek sauce.

### Table 3. Antioxidant properties of Golek sauce before and after retort processing

| Recipes | Before retort processing | After retort processing |
|---------|--------------------------|-------------------------|
| 1       | 375.70±1.82b             | 398.49±2.21a            |
| 2       | 859.61±0.03              | 859.61±0.03             |
| 3       | 1201.84±0.01             | 1273.97±0.02            |

### Table 4. Sensory evaluation of the Golek sauce

| Recipes | Appearance | Color | Odor | Taste | Overall acceptability |
|---------|------------|-------|------|-------|-----------------------|
| 1       | 5.90±0.40a | 6.27±0.40a | 6.07±0.45b | 5.60±0.31a | 6.00±0.31a |
| 2       | 6.67±0.30a | 6.60±0.31a | 5.87±0.26b | 6.00±0.29b | 6.33±0.26b |
| 3       | 4.43±0.33a | 4.30±0.36b | 5.30±0.29a | 5.10±0.33a | 5.23±0.30b |

The different superscripts in a column differ significance (p<0.05), Mean ±SD, n=3.
3.2. Retort Processing

The thermocouple assessment of core temperature, showed that the temperature gradually increases with an increased processing time (Figure 3). A reference temperature of 121°C was used to calculate the lethality of *C. botulinum*, with the come-up time for fried rice with Golek sauce reaching 80°C in 15 min. After 80°C was reached, the product was subjected to the steam-air mixture, and the product temperature rose up close to 117°C within 60 min. After achieving the desired F0 value, the product temperature of 117°C was brought down to 40°C by pressurized water cooling. The retort process parameters, such as heating lag factor index (1.39) and heating rate index (38.26). The retort temperature was maintained at 117°C for this product and an F0 value of 5.0 was achieved. In the case of a low acid food (pH>4.6, a<sub>w</sub> >0.85) in a hermetically sealed container, an F0 value of at least 3 min is required [3]. The sterilized products were analyzed for microorganisms and none was detected in any of the experiments (Table 5). These results suggested that the thermal process effectively killed all microorganisms. This is consistent with a previous study that reported that the total plate count of Thai food, subjected to commercial sterilizing conditions at 121°C with an F0 of 5 min, was lower than the standard for canned food, with no flat sour microorganisms found [8].

A previous study showed that undertaking sterilization at 116°C, at an initial core temperature of 30.5°C, followed by an F0 at 5.1 min, that spores of *C. Botulinum* and other species were completely inactivated. This led to the highest satisfaction scores related to the color, flavor, and texture of the rice and shrimp, and consequently overall acceptability. However, the thermal process conditions under a long period of high temperature resulted in the Maillard reaction, leading to changes in the color, odor, taste, and texture of the products. Retort treatment at 116°C led to a significant decrease of the L* value, whereas the a* and b* values were significantly increased (p<0.05) [1].

| Month | TPC 35°C | TPC 55°C | Sulfide spoilage | Flat sour mesophile | Mesophilic anaerobe | Thermophilic anaerobe | *C. botulinum* |
|-------|----------|----------|------------------|---------------------|--------------------|----------------------|----------------|
| 0     | ND       | ND       | Negative         | Negative            | Negative           | Negative             | ND             |
| 6     | ND       | ND       | Negative         | Negative            | Negative           | Negative             | ND             |

ND: not detected.

Table 5. Microbial characterization of the fried rice with Golek sauce product

Figure 2. Golek sauce a is recipe 1 (without rice ingredient), b is recipe 2 (contained jasmine rice), and c is recipe 3 (contained black glutinous rice)

Figure 3. Heat penetration into the fried rice with Golek sauce
3.3. Effects of Retort Processing on the Color, pH, and Proximate Composition of the Fried Rice with Golek Sauce

The color values of the fried rice with Golek sauce are shown in Table 6. No significant difference was observed in the L* value of fried rice with Golek sauce. The L* value of fried rice with Golek sauce before and after retort processing at 116°C and an F0 value of 5 was 57.44 and 56.10, respectively. Alternatively, the a* value increased from 30.38 to 33.42, and the b* value increased from 47.41 to 53.77. In regards to the color values of the texture vegetable protein (TVP), which was fried in the Golek sauce, its L* value before the retort processing was 42.30, before decreasing to 38.30 after the retort processing. The a* value increased from 20.22 to 24.76, and the b* value increased from 18.83 to 23.18. Color changes were found to occur due to the Maillard reaction, a chemical reaction brought about by a reduction in sugars, such as glucose and fructose, and amino groups producing glucose-amine compounds [27]. The Maillard reaction was likely due to the protein contained in the coconut milk, the main ingredient in Golek sauce [28]. In line with our present results, the effects of the sterilization temperature and pressure on the quality of cooked rice. It was found that the L* values of cooked rice heated at 80, 100, 120, and 140°C under pressures of 0, 1, 3, and 5 bar, decreased and the rice underwent rapid gelatinization [29].

The pH value of the product increased from 6.07 to 6.35 after retort processing (Table 7), indicating that the pH did not change too much during retort processing. In agreement with our present findings, Chettinad goat meat curry to increase by 0.4 pH units after retort processing. The authors concluded that pH changes during heating may be caused by the splitting of hydrogen bonds during heating and releasing additional protons [30].

The moisture values, water activity indices, and proximate composition, such as protein, fat, and ash content of the product before and after retort processing, are displayed in Table 7. The moisture content of the product increased from 50.32 before retort processing to 62.42 after processing and the water activity value of the product increased from 0.93 to 0.95. This was due to the swelling of starch granules during heating and releasing additional protons [31].

Before commencing retort processing, the proximate composition of the product, including its fat and ash contents, were 5.77 and 0.80, respectively, increasing to 5.98 and 0.83, respectively, after retort processing. The protein and carbohydrate contents were initially 4.15 and 39.01, respectively, before decreasing to 4.10 and 26.67, respectively, after retort processing. Even so, retort processing does not have a significant difference on the ash and protein. As expected, the carbohydrate content was quite high because of the high proportion of rice in the product. The increased fat and ash content and decreased protein content of the product was due to the heating of coconut milk above 80°C, which made it susceptible to protein denaturation, resulting in an unstable coconut milk emulsion [32]. This was because of oil hydrolysis driven by lipase activity, which depended on the temperature, with the free fatty acid content of coconut milk increased with heating time.

3.4. Effect of Retort Processing on the Texture Profile of the Fried Rice with Golek Sauce

Texture analysis is an important means for measuring the physical characteristics of a product. Table 8 displays the results for the hardness, cohesiveness, and chewiness of the fried rice with Golek sauce before and after retort processing. Significant difference was observed in hardness, cohesiveness, and chewiness of before and after retort processing the product. The hardness value decreased from a value of 16.03 to 3.04, while the cohesiveness and chewiness decreased from 0.1 to 0.07 and 0.06 to 0.02, respectively. The starch granules, which are the main structure of rice, were heated and denatured the hydrogen bonds, leading to water absorption and swelling. Furthermore, amyllose in the starch granules were released and formed gel, however, increasing the time for sterilization may break the hydrogen bonds in the structure of the starch granules so that it becomes more denatured. The gelatinization of starch granules was associated their longitudinal and transversal expansion, which can decrease hardness, cohesiveness, and chewiness [33]. These findings are in agreement result with a previous study, which reported retort processing to increase moisture content, but decrease hardness and chewiness [34].

The hardness value of the TVP with Golek sauce increased from 4.76 to 9.20, thus was consistent with the increase in cohesiveness (0.29 to 0.45) and chewiness (0.38 to 1.32) values, respectively. After retort processing, the changes in the texture profile of the TVP with Golek sauce led to evaporation of free water molecules, with a in a, increasing the hardness, cohesiveness, and chewiness.

Table 6. The colors of fried rice and TVP in the product before and after retort processing

| Product          | Color | a*   | b*   |
|------------------|-------|------|------|
| **Fried rice**   |       |      |      |
| Before retort processing | 57.44±0.07* | 30.38±0.04* | 47.41±0.04* |
| After retort processing | 56.10±0.01* | 33.42±0.07* | 53.77±0.01* |
| **TVP**          |       |      |      |
| Before retort processing | 42.30±0.02* | 20.22±0.02* | 18.83±0.02* |
| After retort processing | 38.43±0.01* | 24.76±0.02* | 23.18±0.02* |

* Differences significant within a column at (p<0.05) by paired t test, Mean ±SD, n=3.
4. Conclusion

Fried rice with Golek sauce, a traditional meal product, was developed, packed, and processed in a retort bowl. The retort temperature was maintained at 116°C with an F0 of 5 min. The effects of sterilization on the product’s physicochemical characteristics and proximate composition were investigated. The product was judged to have good acceptability with no microorganisms detected after 6 months of storage at ambient temperature. The present study suggests that retort processing is suitable for the long-term storage of a fried rice with Golek sauce product as it maintains acceptable quality and safety. The product should satisfy the market demand for traditional products which are ready-to-eat and convenient.

3.5. Sensory Analysis of Fried Rice with Golek Sauce

The sensory evaluation measurements of the products performed after retort processing at 116°C with an F0 of 5 are shown in Table 9. Based on a 9-point hedonic scale, the evaluation scores were 7.54 for appearance, 7.77 for color, 7.65 for odor, 7.74 for texture, 7.54 for taste, and 7.76 for overall acceptability. The range of acceptable scores for each parameter was between 7-8, meaning that the testers ‘liked it slightly’ to ‘liked it moderately’. The scores of acceptable appearance and color went hand in hand with the scores on L*a*b* color values. The acceptable texture score also went hand in hand with the texture analysis scores on hardness, cohesiveness, and chewiness, leading to the fried rice with Golek sauce product being acceptable to the panelists.

4. Conclusion

Consistent with our findings, the thermal treatment of soy protein isolate tofu (retorted at 121°C and 110°C) also caused increases in hardness, cohesiveness and chewiness. It is possible that the textural changes noted during the retort processing can be partly attributed to the disulfide bonds that are formed during heating and the hydrophobic interactions that took place [4].

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Table 7. Proximate composition, water activity and pH of the fried rice with Golek sauce product before and after retort processing

| Product          | Moisture (%) | Protein (%) | Fat (%) | Carbohydrate (%) | Ash (%) | Water activity (%) | pH    |
|------------------|--------------|-------------|---------|------------------|---------|--------------------|-------|
| Before retort processing | 50.32±0.03<sup>a</sup> | 4.15±0.04<sup>b</sup> | 5.77±0.02<sup>b</sup> | 39.01±0.07<sup>a</sup> | 0.80±0.04<sup>b</sup> | 0.93±0.00<sup>b</sup> | 6.07±0.01<sup>b</sup> |
| After retort processing  | 62.42±0.01<sup>a</sup> | 4.10±0.01<sup>b</sup> | 5.98±0.01<sup>b</sup> | 26.67±0.02<sup>b</sup> | 0.83±0.01<sup>b</sup> | 0.95±0.00<sup>b</sup> | 6.35±0.01<sup>b</sup> |

<sup>a,b</sup> Differences significant within a column at (p<0.05) by paired t test, Mean ±SD, n=3.

Table 8. Texture profile of the fried rice with Golek sauce product before and after retort processing

| Product          | Hardness | Cohesiveness | Chewiness |
|------------------|----------|--------------|-----------|
| Fried rice in the product Before retort processing | 16.63±0.03<sup>a</sup> | 0.10±0.01<sup>b</sup> | 0.06±0.01<sup>b</sup> |
| Fried rice in the product After retort processing  | 3.04±0.01<sup>a</sup> | 0.07±0.01<sup>b</sup> | 0.02±0.01<sup>b</sup> |
| TVP in the product Before retort processing | 4.76±0.01<sup>b</sup> | 0.29±0.01<sup>a</sup> | 0.38±0.01<sup>a</sup> |
| TVP in the product After retort processing  | 9.20±0.01<sup>b</sup> | 0.45±0.01<sup>a</sup> | 1.32±0.01<sup>a</sup> |

<sup>a,b</sup> Differences significant within a column at (p<0.05) by paired t test, Mean ±SD, n=15.

Table 9. Sensory evaluation of fried rice with Golek sauce

| Product          | Appearance | Color | Odor | Texture | Taste | Overall acceptability |
|------------------|------------|-------|------|---------|-------|-----------------------|
| Fried rice with Golek sauce | 7.54±0.96   | 7.77±1.07 | 7.65±1.23 | 7.74±1.07 | 7.54±1.01 | 7.76±0.99             |

Mean ±SD, n=100.
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