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Effects of Drying Temperature on Quality Parameters of Thai Fermented Fish Dip (Jaew Bong)

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Abstract

Fermented fish dip is a popular condiment in Thailand and the Lao People's Democratic Republic. Thai fermented fish dip (TFFD) can be dried to increase its shelf life and ease of transportation. Dried TFFD can be rehydrated to return the powder to its original, paste-like form. Pre-cooked TFFD paste was dried at three different temperatures (40, 60, and 80 ^oC). Total plate count, yeast and mould count, CIE colour values (L*, a*, and b*), non-enzymatic browning, and sensory scores of the resulting powders were determined. The CIE colour values and sensory scores were also analysed for rehydrated TFFD. Increasing the drying temperature did not affect the total plate count or yeast and mould count. When dried at 80 ^oC , the L* value of TFFD powder was reduced, although the a* and b* values were unaffected compared with lower temperatures. All CIE colour values of rehydrated TFFD decreased as drying temperature increased. Drying temperature did not affect the sensory scores of dried TFFD powder. However, rehydrated samples that had been dried at 80 ^oC had significantly lower sensory colour scores than those dried at 40 or 60 ^oC . Overall preference rankings of dried and rehydrated TFFD dried at 40 and 60 ^oC were better than for those dried at 80 ^oC. Due to an undesirable colour change in the rehydrated product, 80 ^oC was deemed to be an unsuitable temperature for drying TFFD paste. In conclusion, both 40 and 60 ^oC are appropriate temperatures for drying the product.

Keywords: Drying temperature; Fermented fish dip powder; Dehydrated Thai chilli paste; Rehydrated quality; Chilli-based product; Thai condiment

1 Introduction

Fermented fish dip is a condiment that is popular in the north-eastern and central regions of Thailand. The product is also commonly consumed in Lao People's Democratic Republic (Lao PDR), a neighbouring country of Thailand. Fermented fish dip is known in the Thai language as Jaew Bong, Plara Bong, or Nam Prik Plara; and in the Lao PDR language as Jaew Pla Dak. Thai fermented fish dip (TFFD) is composed of fermented fish paste (Plara), dried chilli, and fresh herbs including galangal, lemon grass, red shallot, and garlic. Galangal and lemon grass are sliced and used fresh. Red shallot and garlic are pan-roasted, grilled, or baked and peeled prior to combination. The ingredients are combined and pounded into a paste (Thai Industrial Standards Institute, 2013), after which taste- and flavour-enhancing ingredients such as fermented fish sauce, tamarind paste, and sugar may be added (Duangsai, Srisataporn, Hauisan & Gawbor-

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isut, 2019; Posri, 2008). TFFD paste is typically served with glutinous rice, fried or roasted meat, and fresh or steamed vegetables. The viscous paste is able to stick well to the rice, meat, or vegetables, which balances the taste and heat of TFFD (Duangsai et al., 2019; Posri, 2008; Teaupun, 2009). In the past, TFFD was prepared in the home and served uncooked. At the present time, TFFD is primarily manufactured in small-scale factories, and the product is fully cooked to eliminate food-borne pathogens such as *Salmonella* spp. and *Staphylococcus aureus* (Thai Industrial Standards Institute, 2013). The quality of TFFD varies depending on the ratio of ingredients and the processing methods used (Posri, 2008). High-quality TFFD contains well-blended ingredients and a desirable herbal flavour (Thai Industrial Standards Institute, 2013). Poor-quality TFFD may show visible separation of liquid from the paste, or have offensive musty or sour flavours associated with spoilage (Thai Industrial Standards Institute, 2013). Colour is a vital element in assessing the quality of uncooked TFFD, because it can be indicative of the freshness and level of heat in the product (Posri, 2008; Ratchatachaiyos, 2007). Cooked TFFD can be expected to be darker in colour than the raw product due to non-enzymatic browning reactions that occur during the cooking process (Posri, 2008).

The pH of commercial TFFD ranges from 4.42 to 5.4 (Posri, 2008). The moisture content and water activity (a_w) of commercial TFFD are 48.61-64.40% and 0.82-0.86 respectively (Posri, 2008). Its medium/low acidity and intermediate moisture and a_w levels make TFFD prone to spoilage, therefore shortening its shelf life (Duangsai et al., 2019; Hiraga, Stonsaovapak, Sittipod & Mahakarnchanakul, 2008; Posri, 2008). Additionally, the high moisture content of the product means that liquid leakage may occur during transportation, and the transportation weight may be high (Duangsai et al., 2019).

Drying is a widely used method for preserving food. Reduction of the a_w to < 0.66 prevents microbial spoilage and prolongs the shelf life of food products (Ulloa et al., 2015). In the case of TFFD, the removal of moisture also eliminates the transportation issues described previously. Dried TFFD may be ground or pulverized, to be used as an instant powder. Appropriate amounts of water can be added to rehydrate the powder, returning the dried TFFD to the original paste-like form.

Utilization of the drying process is limited in foods containing heat-sensitive compounds (Ahmed, Shivhare & Ramaswamy, 2002). Chilli and herbs - key ingredients contributing to the freshness, heat, and flavour of TFFD - contain heat-sensitive colour pigments and volatile oils, respectively. Although the effects of the drying process on the quality of dried TFFD have not been reported, it is likely that these ingredients will be adversely affected by the heat of the process. The negative effects of dehydration on the colour of capsicums and chilli-based products have been found to be caused by non-enzymatic browning reactions and thermal degradation of colour pigments (Ahmed et al., 2002; Arslan & Ozcan, 2011; Kim, Lee, Park, Lee & Hwang, 2006; Topuz, Feng & Kushad, 2009; Vega-Galvez, Lemus-Mondaca, Bilbao-Sainz, Fito & Andres, 2008; Vega-Galvez et al., 2009). Using a proper drying temperature may minimize adverse effects and maintain the desired colour and flavour of dried TFFD. The aim of this research was to investigate the quality parameters of dried TFFD powder and rehydrated TFFD, after drying at different temperatures (40, 60, and 80 ^oC), in order to ascertain the appropriate temperature for drying TFFD.

2 Materials and Methods

2.1 Preparation of cooked TFFD

The TFFD was prepared in accordance with a protocol modified from Thathiwan (2017). Briefly, 6 g fermented tilapia paste, 480 g minced galangal, 360 g thinly sliced lemon grass, 900 g minced, peeled, and roasted shallot, 900 g minced, peeled, and roasted garlic, and 240 g tamarind paste were blended using a food processor (MCM 640660, Bosch, Bratislava, Slovakia). Then, 264 g chilli powder, 204 g sugar, and 72 g julienned kaffir lime leaves were hand-mixed into the blended herbs. Fermented tilapia paste was purchased from a local factory (Phetdam Foods Co. Ltd., Kalasin, Thailand) and kept at ambient temperature as recommended by the manufacturer. Other ingredients were purchased from a local supermarket (Tesco Lotus, Khon Kaen, Thailand). The resulting TFFD was divided into three equal portions, each of which was weighed and cooked as recommended by the Thai Industrial Standards Institute (2013). This involved heating on the stovetop until the internal temperature reached 70 ^{o}C and then simmering for 15 min (Official Methods of Analysis of the Association of Official Analytical Chemists, 1990). The cooked TFFD portions were packed into polypropylene plastic bags, kept in a refrigerator at 4 ^{o}C, and used for the experiment within 3 h.

2.2 Drying and rehydration of cooked TFFD

The three portions of cooked TFFD were spread on silicon baking mats to a thickness of 2 mm and dried in a hot-air oven at either 40, 60, or 80 ^{o}C until the a_w reached 0.66 or lower (Ulloa et al., 2015). The a_w assessment was conducted using an Aqua Lab Series 4TEV water activity meter (Aqua Lab, Pullman, WA, USA). Each sample was then aseptically removed from the mat with a sterilized spatula, weighed, and the microbial content analysed. The samples were pulverized prior to assessment of CIE colour values, non-enzymatic browning, and sensory acceptability. Dried TFFD powder samples were rehydrated with hot water. The rehydrated pastes were also analysed for CIE colour values and sensory acceptability. All experiments were repeated in triplicate using three lots of fermented fish.

2.3 Analysis of dried TFFD

Microbial content

Analysis of microbial content involved measurement of the total plate count (TPC) and yeast and mould count (YM). The TPC was determined using a published protocol (Al-Harbi & Uddin, 2005) after culturing on standard plate count agar (BBL, Sparks, MD, USA) at 30 ± 0.1 ^{o}C for 48 h. The YM was determined after culturing on acidified potato dextrose agar (BBL, Sparks, MD, USA) at 23-25 ^{o}C for 5 days (Mislivec & Stack, 1989). All microbial counts are expressed as log CFU g^{-1} sample.

CIE colour values

The samples were analysed for CIE colour values (L*, a*, and b*) using a Konica Minolta CM-2600d spectrophotometer (Konica Minolta, Inc., Japan). A D65 artificial daylight bulb and 10^{o} standard angle observer were used to illuminate the samples. The L* value indicates lightness, while a* and b* are the red/green and yellow/blue coordinates respectively.

Non-enzymatic browning

Non-enzymatic browning was assessed using the method described by Dissaraphong, Benjakul, Visessanguan and Kishimura (2006). Briefly, 5 g of dried TFFD powder was combined with 50 mL of ethanol 50% (v/v), stirred continuously for 60 min, and filtered with Whatman No. 1 filter paper. The absorbance of the filtrate was determined at 420 nm using a Spectronic-15 spectrophotometer (Thermo Scientific, Thermo Fisher Scientific India Pvt. Ltd., Nasik, India).

Sensory score evaluation

Sensory acceptability (colour, odour, texture, flavour, and overall acceptability) was evaluated using a nine-point hedonic scale according to Meilgaard, Civille and Carr (1991) (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely). Prior to evaluation, samples were randomly assigned a three-digit number and presented to 45 panellists acquainted with TFFD. The panel was composed of 18 females and 17 males with ages between 20-50 years. All sensory evaluations were conducted in an air-conditioned room at 25 ^{o}C. A score of 5 was considered the limit of acceptability for all sensory parameters. Overall preference ranking according to Lu (2017) was also evaluated, with a ranking of '1' meaning most preferred. Any undesirable sensory characteristics noted by the panellists were recorded.

2.4 Analysis of rehydrated TFFD

Samples of dried TFFD powder were rehydrated with hot water (temperature > 90 ^{o}C). The amount of water added to the powder was calculated according to equation (1). The samples were allowed to absorb the water for 30 min and then stirred continuously for 2 min. CIE colour values and sensory tests were then evaluated as described in section 2.3.

$$WT_{reh} = W_{uncook} - W_{dried} \quad (1)$$

where WT_{reh} is the amount of hot water used for rehydrating the sample (g), W_{uncook} is the weight of uncooked TFFD (g), and W_{dried} is the weight of dried TFFD (g).

2.5 Statistical analysis

The experiment was carried out using a randomized complete block design (RCBD). Data were analysed using SAS University Edition (SAS Institute Inc., Cary, NC) with a 95% confidence level. The calculated means were compared using the least significant difference (LSD) test. Overall preference rankings were compared using Friedman's test as recommended by Meilgaard, Carr and Civille (2006).

3 Results and Discussion

3.1 Analysis of dried TFFD

Microbial content

The calculated TPC and YM values of dried TFFD samples are shown in Fig. 1. TPC and YM showed no significant difference ($p > 0.05$) between the three drying temperatures. The results indicated that increasing the drying temperature did not promote microbial destruction. It has been reported that some microorganisms are destroyed in the drying process. However, many microorganisms - such as bacterial endospores, yeasts, moulds, and several Gram-negative and Gram-positive bacteria - are resistant to dehydration (Jay, 2000). Our results indicated that the tested TFFD may have contained microorganisms that were able to withstand drying temperatures of ≤ 80 ^{o}C . Herbs and spices contain microorganisms indigenous to the soil and plants where they are grown, often including heat-resistant spore-forming bacteria which are able to survive the drying process (Farkas, 2001; Fellows, 2000). It is likely that the heat-resistant microorganisms in the TFFD originated from the herbal ingredients in the product.

These results were in agreement with Orphanides, Goulas, Botsaris and Gekas (2017) who found that increasing drying temperature from 40 to 70 ^{o}C did not affect the TPC of dried spearmint samples. Bourdoux, Li, Rajkovic, Devlieghere and Uyttendaele (2016) suggested that the complex structures and compositions of fruits, vegetables, herbs, and spices may explain the high variability in survival rates of microorganisms during the drying process. Complex structures of the herbal ingredients included in TFFD may therefore provide protection for microorganisms, explaining the unchanged TPC and YM values of the dried samples.

CIE colour values

The CIE colour values of dried TFFD are shown in Fig. 2. The results showed that increasing the drying temperature to 80 ^{o}C significantly reduced the L* value of dried TFFD, compared with 40 and 60 ^{o}C ($p < 0.05$) (Fig. 2 a). However, L* values showed no significant difference ($p > 0.05$) between 40 and 60 ^{o}C . The three temperatures had no effect on the a* and b* values ($p > 0.05$) (Fig. 2 b and c). The reduction of L* value may have resulted from increased non-enzymatic browning at higher temperatures. To our knowledge, the effect of drying temperature on the colour values of dried TFFD has not yet been reported. In both uncooked and cooked TFFD, non-enzymatic browning has been reported to be a cause of colour change (Posri, 2008). Changes in the colour values of dried jumbo squid and Atlantic salmon fillets are reported to be due to non-enzymatic browning, and are more prominent in samples exposed to high drying temperatures of 50 ^{o}C or more (Ortiz et al., 2013; Vega-Galvez et al., 2011). Additionally, the colour changes in dried salted cod (*Gadus morhua*) that occur at higher temperatures have been found to be due to contraction of

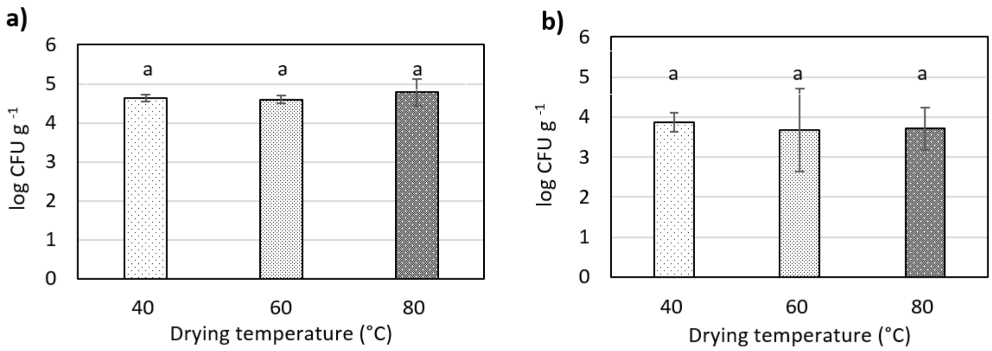

Figure 1: Total plate count (a) and yeast and mould count (b) of dried Thai fermented fish dip as affected by drying temperature. Identical letters above the bars within each parameter indicate counts that are not significantly different at a confidence level of 95%.

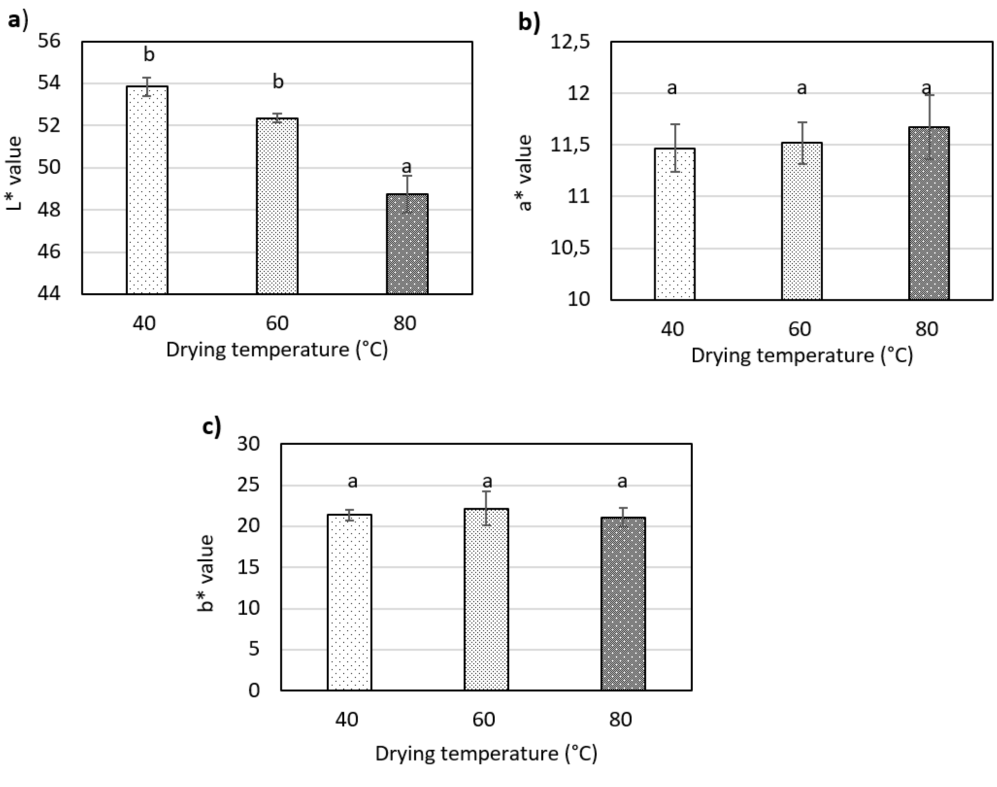

Figure 2: L* (a), a* (b), and b* (c) values of dried Thai fermented fish dip as affected by drying temperature. Identical letters above the bars within each parameter indicate values that are not significantly different at a confidence level of 95%.

muscle myotomes caused by protein aggregation (Ozuna, Gomez Alvarez-Arenas, Riera, Carcel & Garcia-Perez, 2014). Similar contraction of the fish muscle in TFFD at increased drying temperatures may contribute to reduction of the L* value.

Colour changes in dried red pepper and chilli are reported to be caused by non-enzymatic browning and the thermal degradation of colour pigments (Ahmed et al., 2002; Arslan & Ozcan, 2011; Kim et al., 2006). These reports showed that high drying temperatures cause more brown pigments to form, contributing to discolouration of the dried products. Discolouration of dried chilli in TFFD may have occured at 80 ^{o}C , thus reducing the L* value of the dried product. From these studies, it can be hypothesized that non-enzymatic browning of the fish in TFFD contributed to the reduction in the L* value of TFFD dried at 80 ^{o}C . To prevent colour changes in TFFD caused by non-enzymatic browning of chilli, drying temperatures of 40 and 60 ^{o}C are more appropriate than 80 ^{o}C .

Non-enzymatic browning

The results of the assessment for non-enzymatic browning of dried TFFD samples are shown in Fig. 3. The lowest value (0.76) was detected in the sample exposed to 40 ^{o}C , while the highest value (1.97) was found in the sample exposed to 80 ^{o}C . The rate of browning increased significantly as the drying temperature increased ($p < 0.05$). Non-enzymatic browning involves the reaction of carbonyl compounds with amino groups. In muscle-based foods, the carbonyl compounds mainly originate from carbohydrates, in the form of glycogen, reducing sugars, and nucleotides. Amino groups are readily available from the muscle protein (Vega-Galvez et al., 2011). The rate of non-enzymatic browning is reported to be highly sensitive to heat, increasing 2-3-fold for each 10 ^{o}C rise (Gögüs, Fadıloglu & Soysal, 2009).

It has been reported that non-enzymatic browning reactions reduce the colour quality of uncooked TFFD (Posri, 2008), but the effect of drying temperature on the non-enzymatic browning of dried TFFD has not, to our knowledge, been previously reported. Heat from the cooking process increased the rate of browning in TFFD, resulting in the cooked product displaying a darker colour (Posri, 2008). Drying temperatures of 50-90 ^{o}C have been shown to increase non-enzymatic browning reactions in both dried and rehydrated jumbo squid (*Dosidicus gigas*) (Vega-Galvez et al., 2011). Furthermore, Atlantic salmon (*Salmo salar* L.) fillets dried at 60 ^{o}C exhibit more colour change due to non-enzymatic browning compared with those dried at 40 or 50 ^{o}C (Ortiz et al., 2013).

The results led to the conclusion that fermented fish may influence the non-enzymatic browning of TFFD. This ingredient is composed of fish, salt, and carbohydrates such as rice bran or roasted rice, fermented for at least 6 months at ambient temperatures. During the fermentation process, proteolytic enzymes - naturally present in the guts and muscle of fish and those produced by microorganisms - break down the muscular protein into amino acids. Amylases and lipases produced by the microorganisms also cause chemical changes in the product, by releasing sugars from the rice bran or roasted rice (Krusong, 2004). Fermented fish in TFFD may therefore supply significant amounts of free amino acids and reducing sugars, which could contribute to excessive non-enzymatic browning of the product. This theory is supported by the fact that squid - which is also rich in free amino acids - is susceptible to excessive browning. This poses a significant quality problem in dried squid products, especially during the drying process and subsequent storage (Vega-Galvez et al., 2011).

Sensory score evaluation

The sensory acceptability scores of dried TFFD are shown in Fig. 4. Although a slight decrease in the scores was noted as the drying temperature increased, statistical analysis revealed that there was no significant difference in the sensory scores ($p > 0.05$). All samples were rated > 7 (like moderately), higher than the cut-off score of 5. Therefore, dried TFFD powder was considered acceptable.

Overall preference rankings of dried TFFD are illustrated in Fig. 5. There were no significant differences in the scores for TFFD dried at 40 and 60 ^{o}C ($p > 0.05$). The results show that the

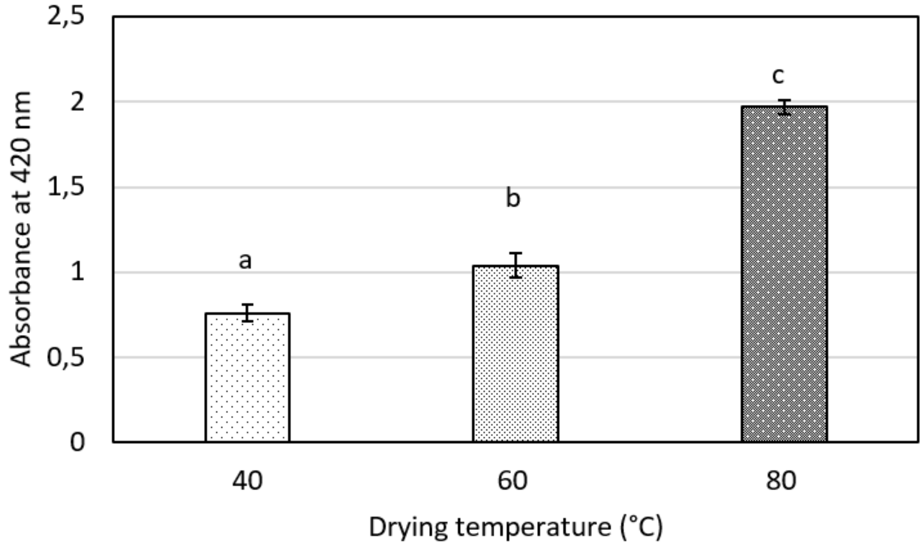

Figure 3: Non-enzymatic browning of dried Thai fermented fish dip as affected by drying temperature. Identical letters above the bars indicate values that are not significantly different at a confidence level of 95%.

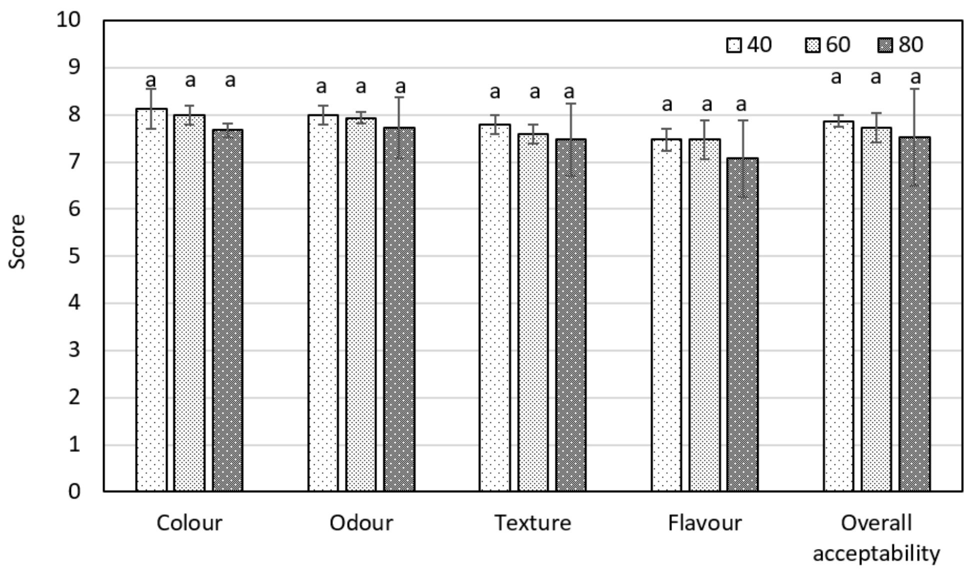

Figure 4: Sensory acceptability scores of dried Thai fermented fish dip as affected by drying temperature. Identical letters above the bars within each attribute indicate scores that are not significantly different at a confidence level of 95%.

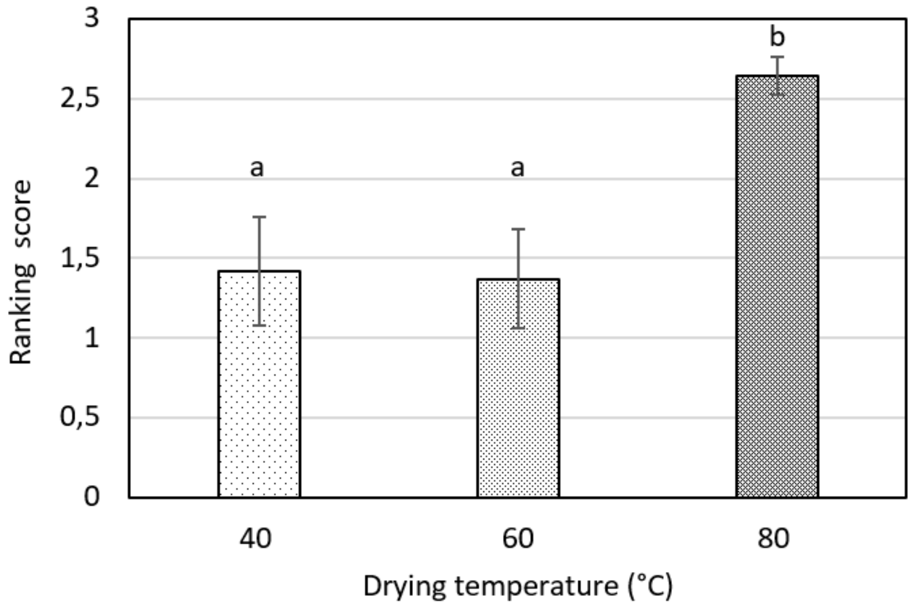

Figure 5: Overall preference ranking of dried Thai fermented fish dip as affected by drying temperature. Identical letters above the bars indicate rankings that are not significantly different at a confidence level of 95%.

average rankings of TFFD exposed to 40 and 60 ^{o}C were significantly better (close to 1) than of those dried at 80 ^{o}C ($p < 0.05$). Undesirable dark colour of TFFD exposed to 80 ^{o}C , recorded by panellists, may cause a worse rank (close to 3). It was clear that treatment at 40 and 60 ^{o}C gave better rankings compared to 80 ^{o}C treatment. Based on these results, drying temperatures of 40 and 60 ^{o}C were considered to be more appropriate for drying TFFD than 80 ^{o}C .

3.2 Analysis of rehydrated TFFD

CIE colour values

The CIE colour values of rehydrated TFFD are presented in Fig. 6. The results show that the L*, a*, and b* values of rehydrated TFFD decreased significantly as drying temperature increased ($p < 0.05$). Non-enzymatic browning may play an important role in the colour changes of rehydrated TFFD, as previously described for dried TFFD. The results revealed that drying at 80 ^{o}C significantly reduced the redness (indicated by the a* value) of the rehydrated TFFD samples. Redness plays an important role in the colour quality of TFFD, because it reflects the freshness and level of heat of the product (Posri, 2008). Drying at a temperature of 80 ^{o}C is therefore not appropriate for TFFD, due to the obvious changes in CIE colour values, particularly the a* value, that occur at this temperature. Several studies have investigated the colour values of rehydrated food products, most commonly products that are intended to be consumed after rehydration (Ulloa et al., 2015; Vega-Galvez et al., 2008; Vega-Galvez et al., 2009; Vega-Galvez et al., 2011). The effects of drying temperature on the colour values of rehydrated fish products have been investigated by Vega-Galvez et al. (2011). As the drying temperature increased from 50 to 90 ^{o}C , the L*, a*, and b* values of

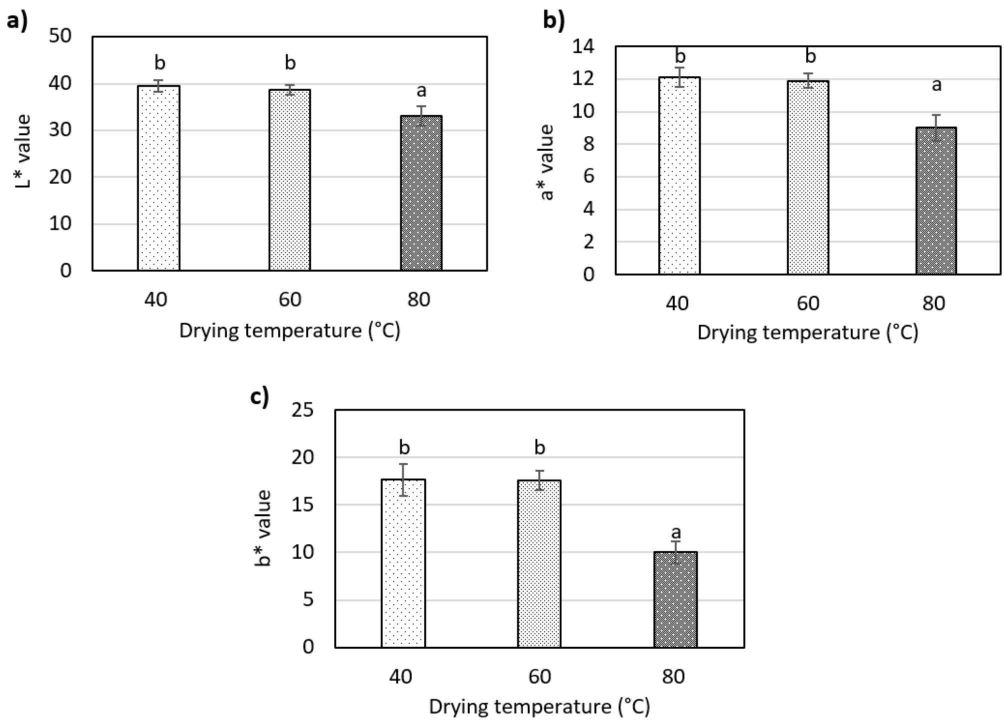

Figure 6: L* (a), a* (b), and b* (c) values of rehydrated Thai fermented fish dip as affected by drying temperature. Identical letters above the bars within each parameter indicate values that are not significantly different at a confidence level of 95%.

rehydrated jumbo squid decreased (Vega-Galvez et al., 2011). Non-enzymatic browning was suggested to be the cause of the colour changes observed in the product.

The results showed a relation between the L* values of dried TFFD and those of rehydrated TFFD. Similar decreasing trends in L* values of dried and rehydrated TFFD were observed as drying temperature decreased (Fig. 2 a and Fig. 6a). However, a* and b* values did not show any relation between dried and rehydrated samples. No reduction of a* and b* values was detected in dried samples (Fig. 2b and c), but reductions were found in rehydrated samples (Fig. 6 b and c). Addition of water to rehydrate TFFD may help the product gain a more homogenous structure, thus able to display more colour variation. Therefore, measurement of colour values in rehydrated TFFD along with dried TFFD is recommended.

Sensory score evaluation

The sensory acceptability scores recorded for rehydrated TFFD are shown in Fig. 7. Odour, texture, flavour, and overall acceptability scores were not significantly different between the drying temperatures ($p > 0.05$). However, the sensory colour score of the samples dried at 80 ^{o}C was significantly lower than those dried at 40 and 60 ^{o}C ($p < 0.05$; Fig. 7). Examination of panellists' records revealed that TFFD dried at 80 ^{o}C exhibited a darker colour, which was deemed to be less acceptable compared with those dried at 40 or 60 ^{o}C . Excessive brown pigments caused by non-enzymatic browning reactions during high-temperature drying may have contributed to a darker colour. The sensory colour scores correlated well with the CIE colour values of rehydrated TFFD (Fig. 6), in which the colour values decreased significantly when TFFD was exposed

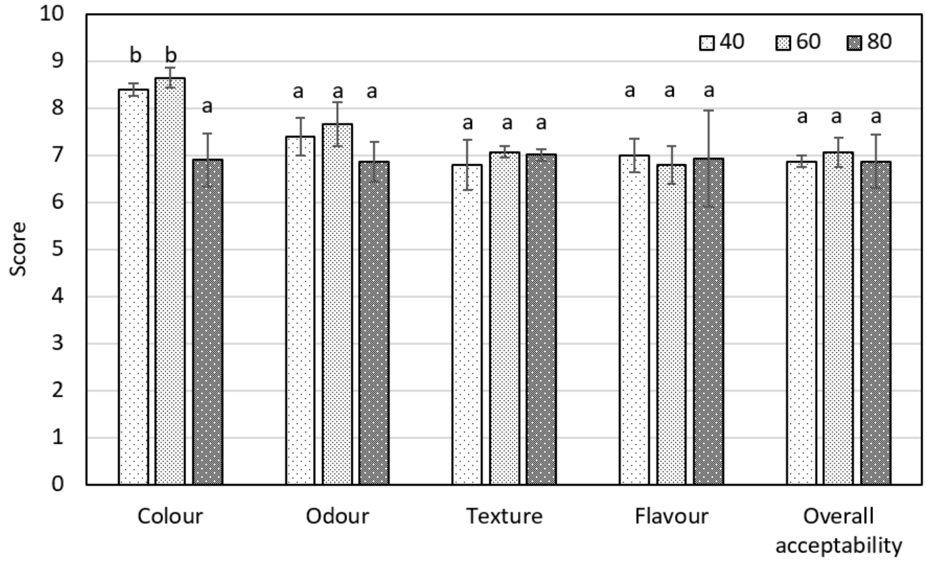

Figure 7: Sensory acceptability scores of rehydrated Thai fermented fish dip as affected by drying temperature. Identical letters above the bars within each attribute indicate scores that are not significantly different at a confidence level of 95%.

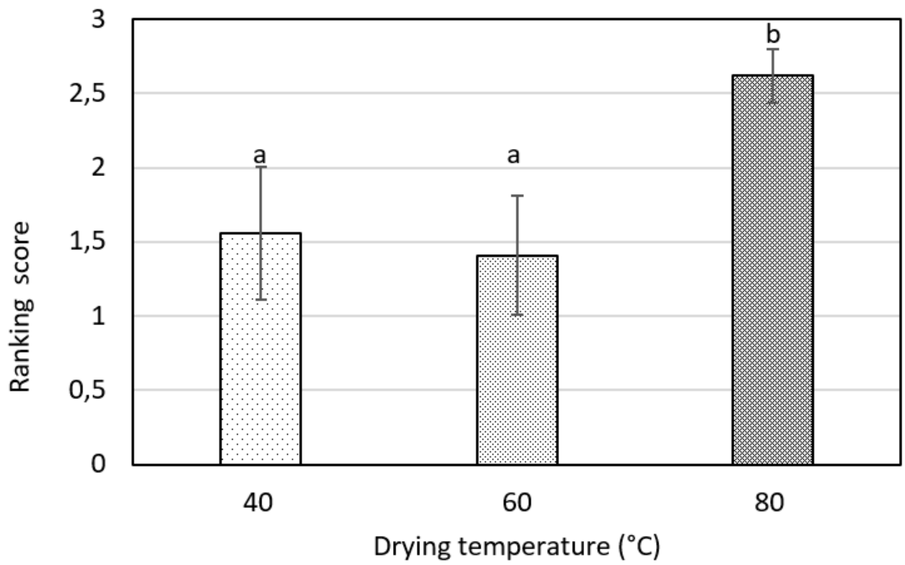

Figure 8: Overall preference ranking of rehydrated Thai fermented fish dip as affected by drying temperature. Identical letters above the bars indicate rankings that are not significantly different at a confidence level of 95%.

to 80 ^{o}C drying temperature. Drying temperatures of 40 and 60 ^{o}C were not significantly different in term of sensory scores ($p > 0.05$; Fig. 7). Overall preference rankings of rehydrated TFFD samples are presented in Fig. 8. The samples exposed to 40 and 60 ^{o}C had rankings of 1.56 and 1.41, respectively. These scores represented better ranks (close to 1) compared to drying at 80 ^{o}C which produced a score of 2.62. Panellists' records confirmed that 80 ^{o}C caused an unpleasant dark colour in rehydrated TFFD. The rankings of rehydrated TFFD (Fig. 8) showed a similar trend to those of dried TFFD (Fig. 5). Therefore, it is clear that 40 and 60 ^{o}C are more appropriate temperatures for drying TFFD than 80 ^{o}C .

4 Conclusions

The microbial content, CIE colour values, and sensory acceptability scores did not differ significantly between TFFD dried at 40 ^{o}C and that dried at 60 ^{o}C . Drying at 60 ^{o}C resulted in increased non-enzymatic browning compared with drying at 40 ^{o}C , but this did not have an adverse effect on sensory colour scores. Drying at a temperature of 80 ^{o}C caused significant changes in the CIE colour values and sensorial colour score, which were particularly evident when rehydrated product was examined. Overall preference rankings of dried and rehydrated TFFD confirmed that 40 and 60 ^{o}C gained better ranks than 80 ^{o}C . Therefore, both 40 and 60 ^{o}C are appropriate temperatures for drying TFFD, but at 80 ^{o}C there was an unacceptable amount of undesirable changes in the product and so that temperature should not be used for drying cooked TFFD.

Based on this study, optimization of drying factors such as time, temperature, and thickness of TFFD for commercial preparation using a mathematic model of data with multivariate analysis should be further investigated. Although dried TFFD is intended to be used as an instant powder, which should be rehydrated prior to consumption, it was found that the powder needed a rehydrating period of 30 min, due to its poor water absorption. Rehydrating for less than 30 min caused solid particles to form at the bottom of the container and separate from the liquid portion. To solve this problem, the addition of food binding or thickening agents to dried TFFD powder should be further explored.

Acknowledgements

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