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Physicochemical, volatile, amino acid, and sensory profiles of instant noodles incorporated with salted duck egg white from various salting durations

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Abstract

The physicochemical, volatile, amino acid, and sensory profiles of salted duck egg white (SDEW) incorporated in instant noodles were studied. There were nine instant noodle samples tested in the present work namely C1: wheat flour; WF; C2: WF ± non-salted duck egg white; T1: WF ± SDEW - 0 d; T2: WF ± SDEW - 5 d; T3: WF ± SDEW - 10 d; T4: WF ± SDEW - 15 d; T5: WF ± SDEW - 20 d; T6: WF ± SDEW - 25 d; and T7: WF ± SDEW - 30 d. The colour coordinates of lightness and yellowness continuously decreased from C2 to T7 ($p < 0.05$). The pH of C1 was the lowest. The cooking yield and optimum cooking time were highest for T7 ($p < 0.05$). Similarly, the hardness, firmness, chewiness, tensile strength, and elasticity were higher for SDEW-added noodles ($p < 0.05$). Conversely, the stickiness decreased but remained high in SDEW-added noodles. The free sulfhydryl (SH) and disulphide (SS) groups were higher in duck egg white (DEW) than in SDEW-added noodles. DEW- and SDEW-added noodles showed a wide range of flavour compounds ($p < 0.05$). Furthermore, there were 19 amino acids detected in the noodles, and SDEW-added noodles showed more and wider variety of amino acids ($p < 0.05$). Sensory characteristics such as colour, roughness, stickiness, firmness, flavour, and overall liking were slightly higher for T5 than the other treatments.

Introduction

Instant noodle is a popular ultra-processed food among the various instant food products commercialised worldwide. It is also a global food product available at low cost, and plays vital role in the national economy, especially on the Asian continent (Wee and Henry, 2020). Instant noodles have a wide range of consumers, and are very popular across all age groups due to their convenience, long shelf life, enjoyable taste, and low price (Farrand *et al*., 2017). According to a report from the World Instant Noodles Association (WINA), the demand for instant noodles is increasing by 3% annually, and 103,620 million servings of instant noodles were sold globally in 2008. In Asia, aside from rice, noodles have been a primary staple food for centuries. In Thailand, 3,570 million servings of instant noodles were sold in 2019, and the number keeps increasing each year (WINA, 2020). Thailand's Ministry of Commerce has reported that the demand for instant noodles was increased by 11% each year, and the export value reached USD 57.8 million in 2020. Instant noodles are prepared using wide variety of ingredients; but, the noodle strands are predominantly made using wheat flour, either refined or unrefined. Other ingredients are also included in the noodles to enhance their flavour and texture profiles. Spices and seasoning mixtures for instant noodles vary by geographic regions and cultural practices. Several studies have reported that continuous consumption of instant noodles could lead to a lower intake of protein, calcium, phosphorus, iron, potassium, niacin, vitamin A, and vitamin C because wheat flour lacks essential nutrients (Farrand *et al*., 2017).

Recent advancements in noodle-making include adding egg white that could improve the physical and nutritional qualities of noodles. Deleu *et al.* (2016) reported that egg white in wheat flour could facilitate chemical bonding during thermal treatment, thus improving the physical strength of the food product, particularly dough-related foods such as noodles, pastas, pastries, and pizzas. Generally, chicken eggs are the key ingredient in a wide range of food products. Duck eggs are actually equally nutritious as chicken eggs, but are still not widely

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incorporated in foods due to their unique flavour (Zhao *et al.*, 2014). Salted duck eggs are widely produced in Asian countries especially China, Thailand, Malaysia, Indonesia, and Vietnam (Kaewmanee *et al.*, 2011). In Thailand, the production of salted duck eggs is found predominantly in the southern regions, especially in Surat Thani province. Traditionally, salted duck eggs are produced by covering the eggshell with a salt-infused mud coating along with rice chaff ash (Venkatachalam, 2018), also known as salting. Salting extends the shelf life of eggs as during salting, salt in the mud coating gradually infuses into the eggshell, and then into the egg white and yolk. Salting alters the egg drastically; the egg yolk becomes more solid, and turns into a beautiful orange colour, whereas the egg white becomes watery, cloudy, and salty (Venkatachalam, 2018). Salting duration controls the intensity of duck egg alteration; short duration gives only minimal effects on the eggs (Kaewmanee *et al*., 2011), while prolonged salting produces egg yolks that can be used in Chinese mooncakes, and in many other baked confectionery products.

A considerable amount of unusable salted duck egg white (SDEW) is produced as by-product, and often discarded. The poor usability of SDEW is mainly due to its extreme saltiness; its functionality is hugely diminished by the salt content (5 - 7%) in egg white from prolonged salting. Limited studies have explored the usability of SDEW, and these studies were focused on expensive enzymatic hydrolysis and desalination using various membrane techniques (Venkatachalam and Nagarajan, 2019). Until now, there are no prior studies on using SDEW as an ingredient in instant noodles. SDEW could be an excellent alternative for water, and provide the salt needed in the making of instant noodle. It could also improve the nutritional value of instant noodles as egg white contains an abundance of macro- and micronutrients. The present work thus aimed to incorporate SDEW from various salting durations in instant noodle formulations, and to examine various physicochemical properties as well as consumers' acceptability of the finished instant noodle products.

Materials and methods

Raw material preparation

Salted duck eggs (Khaki Campbell) at various salting durations (0, 5, 10, 15, 20, 25, or 30 d) were procured from Chaiya district, Surat Thani province, in the southern peninsular part of Thailand. The eggs were cleaned from the salt-infused mud coating, and cracked open to obtain the egg whites. The yolks were discarded. The egg whites from each salting duration were collected, separately added into test tubes to observe the appearance influenced by the salting durations, and photographs were taken accordingly. Prior to noodle preparation, the collected duck egg whites were analysed for protein content (%), salt content (%), and moisture content (%) in accordance with AOAC (2003). Besides, the wheat flour's functional properties including water absorption capacity (WAC, %), fat absorption capacity (FAC, %), gelatinisation temperature (GT, °C), bulk density (BD, %), and swelling capacity (SW, %) were also measured in accordance with Venkatachalam *et al.* (2017).

Instant noodle preparation

Instant noodles were prepared in two stages based on the commercial formula, namely dough preparation and noodle preparation. For dough preparation, the dry ingredients *i.e.*, refined wheat flour (100%), salt (5%), sodium bicarbonate (0.26%), and ascorbic acid (0.04%) were added into a mixing bowl, thoroughly mixed, and added with the wet ingredients. Water (44%) was added gradually to form a dough using an electric mixer at speed level of 2 for 3 min. Once the dough became crumbly, it was removed from the mixer, and hand-kneaded for 5 min to obtain a smooth dough, then wrapped in polyethylene film, and kept in refrigerator for 10 min to make it firm. Then, the dough was cut into small pieces, rolled into small balls (approximately 5 - 6 cm in diameter), and passed into the pasta roller to obtain thin sheets (1.5 mm thickness). The sheets were then cut into noodle strands (25 cm length, 1.5 mm width, and 1.5 mm thickness) using a dedicated noodle cutter attached to the pasta roller. After that, the noodle strands were manually set to instant noodle block shapes, and steamed at 90°C for 2 min using a steamer. After steaming, the noodles were immediately immersed in a pre-heated fryer (150°C) containing cooking palm oil, and fried for 45 s. The fried noodles were then placed in a wire rack, and allowed to cool for 20 min in a sterile air cabinet at ambient temperature, and later were stored in an airtight plastic container. The instant noodles prepared without adding any egg white served as control 1 (C1), and instant noodles prepared with non-salted DEW (44%) served as control 2 (C2). For treatments, the instant noodles were prepared using SDEW (44%) at different salting durations (0, 5, 10, 15, 20, 25, or 30 d), and labelled as treatments T1, T2, T3, T4, T5, T6, and T7, respectively. The eggs replaced the water content, and the SDEW replaced the salt content in the instant noodle recipe.

Colour characteristics and pH

Colour coordinates of lightness (L*), redness (a*), and yellowness (b*) were measured using a Hunter LAB colorimeter (Hunter Associates Laboratory, Inc. Reston, VA, USA) at random points on the instant noodles. To measure pH, the cooked instant noodles (10 g) were homogenised with 100 mL deionised water for 5 min, incubated for 30 min at room temperature, filtered, and the filtrate was measured using a digital pH meter (pH30 Tester, CLEAN, Shanghai, China).

Cooking yield and optimum cooking time

Instant noodles were measured for cooking yield in accordance with AACC (2003). Briefly, noodles (5 g) were boiled in deionised water (75 g) for 10 min with agitation. Then, the boiled noodle strands were drained from water for 5 min. Noodles were then measured for cooking yield, and the results were reported as percentages. Instant noodles were analysed for optimum cooking time also in accordance with AACC (2003). The noodles were confirmed for optimum cooking by checking on the core of the noodle strands. The results were expressed as an optimum cooking time (s).

Free SH and SS groups

Free SH and SS groups in the cooked instant noodles were measured following the method described by Li *et al.* (2018). Briefly, 5 g of cooked instant noodles was mixed with 5 mL of Tris-glycine buffer (pH 8) that contained 0.1 M Tris, 0.1 M glycine, and 4 mM EDTA. After the addition of buffer, 0.1 mL of Ellman's reagent was mixed, and incubated at room temperature for 15 min, followed by centrifugation at 19,000 *g* at 4°C for 15 min. Then, the supernatant was collected and used for measuring the free SH and SS groups. To determine the free SH, 0.5 mL sample was mixed with 2.5 mL Tris-Gly-8 M urea and 0.02 mL Ellman's reagent. The mixture was vigorously mixed and incubated at 25°C for 30 min. After that, the mixture was measured at 412 nm. Eq. 1 was used to estimate the free SH groups:

$$Free\ SH\ \left(\frac{\mu mol}{g}\right) = 73.53\ A\ x\ \frac{D_1}{C} \qquad \text{(Eq. 1)}$$

where, A = absorbance; C = concentration of sample (g/L); and D_1 = dilution factor.

To determine the SS groups, 0.2 mL of sample was added to 1 mL of Tris-Gly-10 M Urea, and after that, 0.02 mL of β-mercaptoethanol was added to the mixture. Then, the mixture was incubated at 25°C for 1 h, followed by adding 10 mL of TCA (12%), and incubation was continued again for 1 h at 25°C. Then, the sample mixture was centrifuged at 3,000 rpm for 10 min. The supernatant was collected and mixed with 3 mL of Tris-Gly-8 M urea and 0.03 mL of Ellman's reagent, and incubated again for 30 min at 25°C. After that, the absorbance was measured at 412 nm. Eqs. 2 and 3 were used to estimate the free SS groups:

$$Total\ SH = 73.53\ A\ x\ \frac{D_2}{C} \qquad \text{(Eq. 2)}$$

$$SS\ \left(\frac{\mu mol}{g}\right) = (SH_{total} - SH_{free})/2 \qquad \text{(Eq. 3)}$$

where, A = absorbance; C = concentration of sample (g/L); and D_2 = dilution factor.

Textural properties

The hardness, chewiness, and stickiness of the cooked instant noodles were measured using a textural analyser (Brookfield Texture Analyzer, model no. CT3, Germany) fitted with a 5 kg load cell following the methods of Sozer and Kaya (2003) and Choy *et al.* (2012). The texture analyser was set as follows: pre-test speed, 1 mm/s; test speed, 1 mm/s; post-test speed, 3 mm/s; strain, 75%; time, 2 s; trigger force, 0.05 N; and data acquisition rate, 200 PPS. Briefly, cooked instant noodles were cut to approximately 100 mm length strands. Then, the noodle strands were placed under a compression rig and measured. The hardness (kPa) (maximum peak at the first compression), chewiness (hardness, cohesiveness, and springiness), and stickiness (measuring negative area under the second peak) were reported from the texture profile analysis curve.

The firmness of cooked instant noodles was measured using the method of AACC (2003). Briefly, cooked instant noodles were cut to approximately 100 mm length strands, and placed on the texture analyser fitted with a 5 kg load cell. The texture analyser was set to measure the firmness as follows: the measuring mode was set to force in compression; pre-test speed, 1 mm/s; test speed, 0.1 mm/s; post-test speed, 10 mm/s; distance, 4 mm; and data acquisition rate, 400 PPS. The firmness (N) was recorded from the peak in a force-time graph.

The tensile strength and elasticity were assessed for the cooked instant noodles following the method of Gan *et al.* (2009) using force in tension mode. Briefly, cooked instant noodles were cut to approximately 200 mm length strands, and placed on the texture analyser fitted with a 5 kg load cell. The texture analyser was set as follows: probe distance, 15 mm; pre-test and test speed, 3 mm/s; post-test speed, 5 mm/s; and distance, 100 mm. Furthermore, the width and thickness of the cooked instant noodles were also measured at three random points. Eq. 4 was used to calculate the tensile strength:

$$\alpha = \frac{F}{A} \qquad \text{(Eq. 4)}$$

where, α = tensile strength (kPa), F = pack force (N), and A = cross-sectional area of the noodle strand (m^2).

The elasticity (kPa) of cooked instant noodles was calculated using Eq. 5:

$$Elasticity = \frac{Fl_o}{tA_o}\ x\ \frac{1}{v} \qquad \text{(Eq. 5)}$$

where, F/t = initial slope (N/s) of the force-time curve, l_o = noodle length between the limit arms (0.015 m), A_o = original cross-section of noodle (m^2), and v = movement of the upper arm (0.003 m/s).

Chromatographic analysis of volatile compounds

Instant noodles were measured for volatile compounds by headspace solid-phase microextraction coupled with gas chromatography/mass spectrometry (GC-MS) with an automatic injector, following the method of Marzocchi *et al.* (2017). Briefly, 3 g of sample of ground noodles was added into a 10-mL amber vial, and sealed with a septum and aluminium caps, after which the sample was equilibrated for 30 min at 40°C, followed by the addition of divinylbenzene / carboxen / polydimethylsiloxane SPME fibre (2 × 0.11 cm and 50/30 mm size) through the septum into the vial, and incubation for 10 min at 40°C. After that, the SPME fibre was desorbed for 7 min at 240°C in a 1:10 split mode. A Rtx-Wax column (fused with silica; 30 m × 0.25 mm, 1.0 mm i.d.) was used for the chromatographic volatile separation. The oven temperature was ramped from 40 to 200°C at 3°C/min, and were kept for 3 min, after which it was gradually increased to 240°C at 10°C/min, and maintained for 5 min. The temperatures of injector, transfer, and ion sources were set to 240, 240, and 200°C, respectively. The carrier gas was helium, and the flow rate was 1.5 mL/min. The emission current for the filament was set to 70 eV. The mass range was set to 30 - 250 *m/z*. The identification of volatile compounds from the instant noodles was performed by comparing their mass spectra with the NIST mass spectral database. The identified volatile compounds in the instant noodles were reported in relative concentrations (%).

Amino acid profile

Instant noodles were hydrolysed with 6 N HCl at 110°C for 24 h before analysing the amino acids with high-performance liquid chromatography (HPLC; Abe *et al.*, 2006). The HPLC system had a multi-fluorescence detector paired with a temperature control module. A Waters Alliance 2695 Chromatography Manager^{TM} was used to collect the data. Eluent A contained AccQ-Tag, and eluent B contained a mixture of acetonitrile (60% v/v in water) and acetone (0.01%). Next, 5 µL of sample of the derivatives was added to a 4 µm AccQTag™ C18 column (150 × 3.9 mm) to perform the separation. The column operating temperature was set to 37 ± 1°C at a constant flow rate of 1 mL/min. The amino acids were detected with a UV detector at 248 nm. The results were reported in mg per 100 g of instant noodles.

Sensory evaluation

The sensory evaluation of cooked instant noodles was performed using the 9-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely). Briefly, 70 untrained panellists aged between 20 and 40 years old were chosen for the evaluation. The samples were assigned with random three-digit codes, and served hot to the panellists. The panellists were then instructed to assess the noodles for colour, flavour, texture, chewiness, taste, and overall quality.

Statistical analysis

All the analyses were done in triplicates, except for the colour and texture measurements, which had 15 replications. The data were expressed as mean ± standard deviation. The results were analysed using the Statistical Package for the Social Sciences by comparing the means using One-way analysis of variance (ANOVA) and Duncan's multiple ranges as *post-hoc* test, with significant difference at $p < 0.05$.

Results and discussion

Egg white appearance, and moisture, protein, and salt contents

Changes in appearance, and moisture, protein, and salt contents of the duck egg white during prolonged salting are shown in Figures 1A and 1B. A clear egg white liquid at 0 d became gradually cloudy, and the colour of egg white slightly changed to greenish yellow during prolonged salting (Figure 1A). The egg whites became extremely cloudy after 30 d of salting. This indicated that the salt diffused from the mud coating influenced the egg white. Moisture content in the duck egg white decreased by 2.85% during prolonged salting (Figure 1B). The prolonged salting could induce the migration of moisture from egg yolk to egg white, thus increasing the moisture level of SDEW. However, results showed a minimal decrease of moisture content in

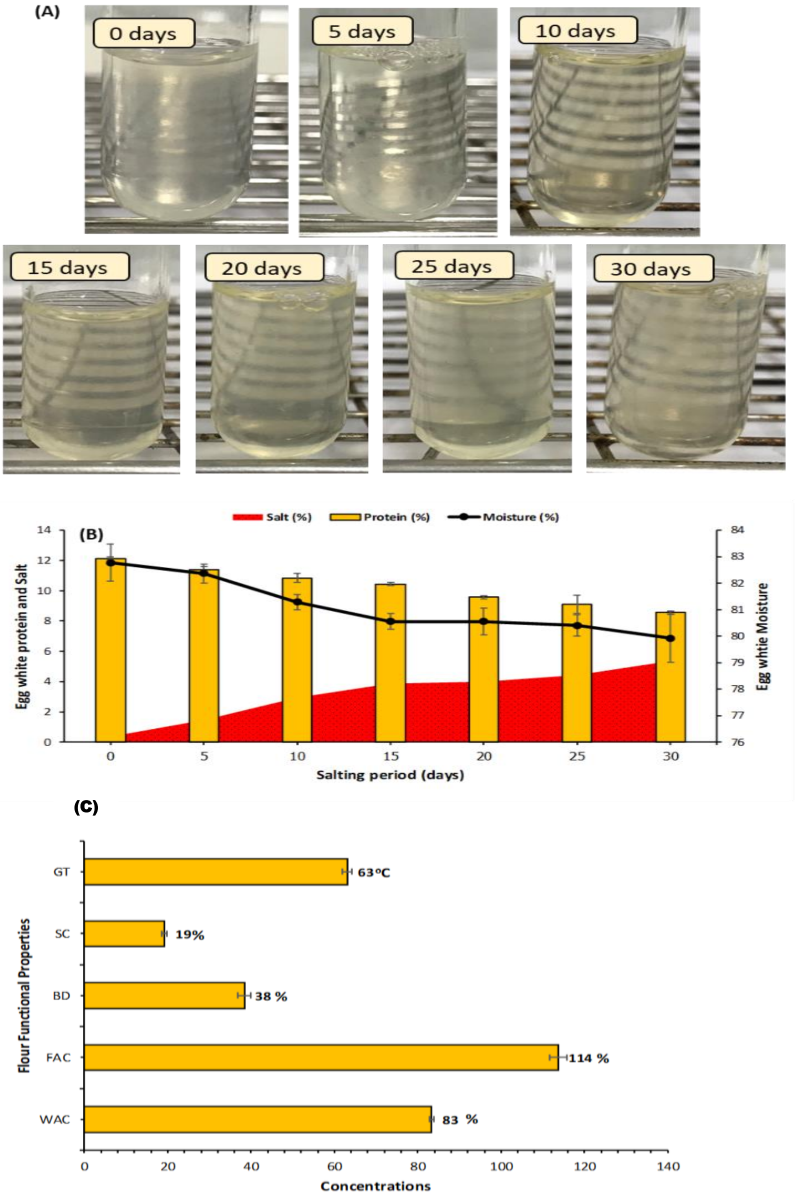

Figure 1. Changes in egg white (appearance, moisture, protein, and salt contents) duck eggs during prolonged salting **(A and B)**, and the functional properties [gelatinisation temperature (GT), swelling capacity (SC), bulk density (BD), fat absorption capacity (FAC), and water absorption capacity (WAC)] of wheat flour used in noodle making **(C)**.

SDEW. This could be due to the prolonged salting duration of SDEW at ambient temperature which could have prompted the migration of moisture from the egg white to diffuse into eggshell and transpired. Since the eggshell was weakened, the salt gradually migrated to the eggshell and egg white, and then to egg yolk. However, the amount of salt in egg yolk was minimal as compared to that in egg white. A total of 5.34% salt was observed in the egg white on the 30th day of salting (Figure 1B). The increase in salt content was partly attributed to the degradation of the shell (Xu *et al.*, 2017). On the other hand, the salt in the egg white slightly affected the protein content in egg white where it decreased from 12.13 to 9.42% (Figure 1B). Salting did not severely alter the protein content in the egg white during 30 d of salting, but it could adversely affect the functional properties (foaming and emulsion) of the protein in egg white (Venkatachalam and Nagarajan, 2019).

Flour functional properties

Wheat flour functional properties such as water absorption capacity (WAC, %), fat absorption capacity (FAC, %), bulking density (BD, %), swelling capacity (SC, %) and gelatinisation temperature (GT, °C) are shown in Figure 1C. Among the various functional properties observed, FAC was the highest in wheat flour. A high FAC indicates an abundant level of non-polar side chains in the protein content of wheat flour, which could bind with the hydrocarbon side chains of oil (Chandra *et al.*, 2015). Choy *et al.* (2010) reported that FAC is determined by the level of protein in the flour; however, this is negatively correlated with the quality of food products such as instant noodles.

WAC of the wheat flour was 83.33%, and was the second highest among the tested functional properties. Studies have shown that, dependent on structural integrity, a wheat starch granule could absorb between 39 and 87% moisture (Berton *et al.*, 2002; Barrera *et al.*, 2013). Furthermore, WAC of wheat flour is also affected by the polar amino groups (Venkatachalam *et al.*, 2017).

Particle size and density of the flour determine BD of the flour. The present work exhibited a comparatively low BD. Low BD is an excellent physical attribute for food products especially cereal flours, whereas high BD is desirable for excellent dispersibility and paste thickness in food usage (Chandra *et al.*, 2015).

SC of the wheat flour was the lowest (19%) among the functional properties.

GT of the flour was 63°C, which was comparatively low. This could possibly help reduce the overall processing temperature of the food product formulation.

Noodle qualities

Colour, pH, optimum cooking time, cooking yield, and free SH and SS groups

The colour coordinates of L*, a*, and b* of cooked instant noodles incorporated with SDEW are shown in Table 1. The L* of the noodles varied, with C1 having a higher L* value than the other treatments with significant difference. The various salting durations of SDEW in instant noodles did not differ much, and on comparing T1 to T7, the differences in L* were only slight. The a* values had a decreasing trend across the treatments, where C1 without salting had a higher a* than the others. The SDEW-incorporated instant noodles had lower a* than C1, thus indicating that these were slightly brighter. The b* values were very similar across all treatments. It was slightly low for C1 than C2 and T1, but for T2 to T7, it showed a gradual decrease in b* values. Gan *et al.* (2009) reported that wheat flour could contribute to the colour changes of instant noodles as it undergoes Maillard reactions and enzymatic browning during processing, and the flavonoids in wheat flour also contribute to the yellowness of instant noodles. The protein content in the noodle formulation could also play a vital role in the darkening of noodles (Wang *et al.*, 2004; Asenstorfer *et al.*, 2010). A higher WAC also contributes to the discoloration of noodles (Morris, 2018) due to the increase in the moisture content in them, thus inducing the interfacial oxidation of tyrosine moieties of polypeptides from the noodles which causes discoloration. In addition, the instant noodle making process exposed the ingredients to high heat, which could adversely affect them by browning reactions based on amino and carbonyl group availability in the formulations.

The pH's of cooked instant noodles incorporated with SDEW are shown in Figure 2A. It was found that the instant noodles had an alkaline pH that slightly varied among the treatments. C1 had the lowest pH, while C2 which contained DEW without salting, had the highest pH. T1 to T7 had a linear trend of decreasing pH's from 8.28 to 7.78 as the salting duration (and salt content in the egg white) increased.

Table 1. Colour characteristics of instant noodles incorporated with salted duck egg white from various salting durations.

Treatment	Lightness (L*)	Redness (a*)	Yellowness (b*)
C1	62.71 ± 0.82^{a}	12.05 ± 0.45^{a}	28.94 ± 0.77^{d}
C2	56.47 ± 0.66^{b}	8.45 ± 0.45^{d}	31.05 ± 0.16^{a}
T1	50.72 ± 0.46^{c}	7.18 ± 0.03^{e}	30.94 ± 0.21^{b}
T2	49.05 ± 0.28^{d}	7.51 ± 0.26^{e}	29.74 ± 0.47^{c}
T3	47.68 ± 0.15^{e}	7.95 ± 0.03^{e}	28.73 ± 0.20^{d}
T4	46.41 ± 0.47^{ef}	8.53 ± 0.02^{d}	28.52 ± 0.08^{d}
T5	43.16 ± 0.07^{g}	9.31 ± 0.11^{c}	26.73 ± 1.02^{e}
T6	40.78 ± 0.13^{h}	9.48 ± 0.04^{c}	24.57 ± 0.03^{f}
T7	39.82 ± 0.25^{h}	10.68 ± 0.04^{b}	22.57 ± 0.80^{g}

Values are mean ± standard deviation (*n* = 15). Means followed by different lowercase superscripts in the same column are significantly different. C1: wheat flour (WF); C2: WF ± non-salted duck egg white; T1: WF ± salted duck egg white (SDEW) - 0 d; T2: WF ± SDEW - 5 d; T3: WF ± SDEW - 10 d; T4: WF ± SDEW - 15 d; T5: WF ± SDEW - 20 d; T6: WF ± SDEW - 25 d; and T7: WF ± SDEW - 30 d.

Normally, the incorporation of protein to instant noodle formulations induced an alkaline pH (Foo *et al*., 2011). SDEW had decreasing pH due to chemical interactions between the egg white and headspace gas in the egg during salting (Venkatachalam, 2018), and this was demonstrated in the present work.

The optimum cooking time of instant noodles was in the 110 s mark (Figure 2B). C1 had the shortest optimum cooking time, although prolonged salting tended to decrease the cooking time gradually. T7 showed a similar cooking time as C1. Prolonged salting had altered the egg white properties, and that shortened the instant noodles' optimum cooking time.

Similarly, the cooking yields of instant noodles also differed. Instant noodles incorporated with SDEW gave high cooking yields, increasing with the duration of salting. C1 and C2 had a slight difference, while T1 to T7 had significant differences.

The free SH and SS groups of cooked instant noodles are shown in Figure 2C. A continuous decrease in SH groups was noticed in the samples. Among them, C1 exhibited the least SH groups, and C2 and T1 which had duck egg white retained slightly more SH groups than the others.

Conversely, the SS groups in cooked instant noodles had an increasing trend with salting of egg white. This indicated that the processing conditions and raw materials significantly influenced the SS groups. The increasing content of SS groups was directly related to the decreasing content of SH groups in the instant noodles. Prolonged salting of egg white has been found to significantly increase SS groups in cooked instant noodles decrease free SH groups (Venkatachalam, 2018). Changes in the free SH groups are considered as an indicator of protein polymerisation through disulphide bonds in noodle making. The free SH groups play significant role in the protein polymerisation through SH oxidation and SH-SS interchange reactions under hydrothermal processing (Li *et al*., 2018). Egg pH is also a critical factor that affects the SH groups, and alkaline eggs could produce strong interactions by SH-SS reactions.

Textural properties

The textural properties of hardness, firmness, chewiness, stickiness, tensile strength, and elasticity of the cooked instant noodles incorporated with SDEW are shown in Figures 3A - 3C. The incorporation of egg white to the instant noodle formulations increased their textural properties. Hardness was higher for C2 and T1 - T7, than for C1 (Figure 3A), and it continuously increased with salting duration. An increase in the hardness of noodles could be caused by firmer and tighter protein

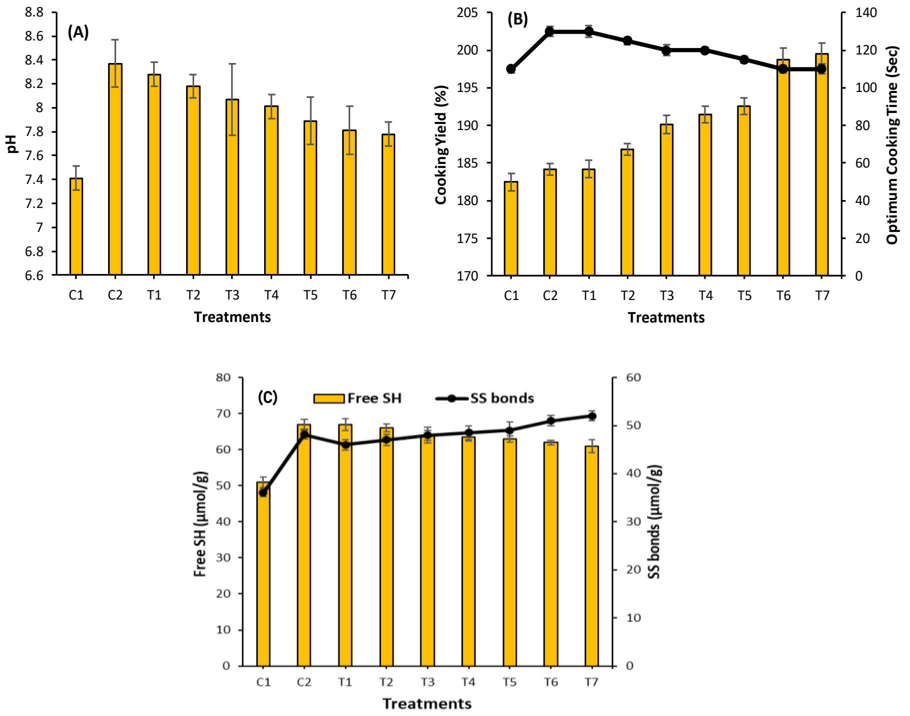

Figure 2. pH **(A)**, cooking yield (%) **(B)**, and free SH and SS bonds **(C)** of instant noodles incorporated with salted duck egg white. C1: wheat flour (WF); C2: WF ± non-salted duck egg white; T1: WF ± salted duck egg white (SDEW) - 0 d; T2: WF ± SDEW - 5 d; T3: WF ± SDEW - 10 d; T4: WF ± SDEW - 15 d; T5: WF ± SDEW - 20 d; T6: WF ± SDEW - 25 d; and T7: WF ± SDEW - 30 d.

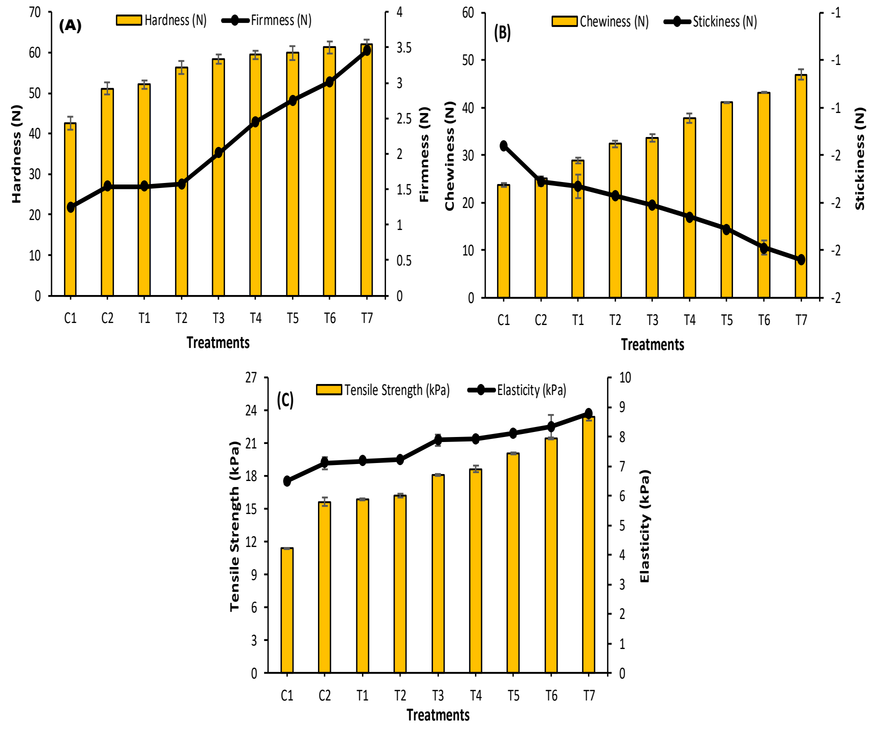

Figure 3. Hardness and firmness **(A)**, chewiness and stickiness **(B)**, tensile strength and elasticity **(C)** of instant noodles incorporated with salted duck egg white. C1: wheat flour (WF); C2: WF ± non-salted duck egg white; T1: WF ± salted duck egg white (SDEW) - 0 d; T2: WF ± SDEW - 5 d; T3: WF ± SDEW - 10 d; T4: WF ± SDEW - 15 d; T5: WF ± SDEW - 20 d; T6: WF ± SDEW - 25 d; and T7: WF ± SDEW - 30 d.

(ovalbumin) networks between the starch granules (Mine, 2002; Kovacs *et al*., 2004).

Similarly, the firmness showed an increasing trend (Figure 3A). Egg white effectively increased firmness of the instant noodles, especially SDEW, as it gave better instant noodle firmness with extended salting of the duck egg white. The level of protein in noodle formulation and a substantial protein network could help the noodle gain a firmer texture (Foo *et al*., 2011). The addition of salt into egg white could induce strong protein-protein interactions that increase firmness (Raikos *et al*., 2007).

The chewiness of cooked instant noodles also increased when duck egg whites were incorporated (Figure 3B), and it steadily increased with the duration of salting. An increase in chewiness in alkaline noodles was mainly attributed to the protein content of SDEW (Tan *et al*., 2016).

The stickiness, however, gradually decreased in egg-incorporated noodles (Figure 3B); C1 was the stickiest while in C2 to T7 the stickiness decreased. On the other hand, the tensile strength and elasticity of the cooked instant noodles gradually increased with salting (Figure 3C); T3 to T6 had increased tensile strength and elasticity. Typically, wheat flour contains gluten which is responsible for the elasticity of noodles. Eggs contribute to the structural integrity of food products, meanwhile gluten and egg albumin in instant noodle formulation could increase elasticity (Adejunwon *et al.*, 2020). Besides, Mine (2002) reported that egg white, when thermally treated in food, could induce elasticity. This is in accordance with the present work.

Volatile compounds

Flavours are critical to the quality of instant noodles. The differences in volatile components and their proportions in SDEW-incorporated instant noodles are shown in Table 2. Seventeen different groups of flavour compounds were identified in cooked instant noodle samples. Among the different noodle samples, C1 had few flavour compounds including aldehydes (1), alkanes (10), and ketones (6), while C2 contained numerous flavour compounds such as alcohols (5), aldehydes (7), alkanes (10), ketones (6), nitriles (8), phenols (9), sulphides and sulphurs (5), and thiazoles (5). The detected volatile compounds in cooked instant noodles significantly varied among the salting durations. Flavours in food are mainly affected by lipid auto-oxidation, protein hydrolysation, and amino acid catabolism. Fu (2008) observed that the incorporation of salt in instant noodles could reduce the cooking time and improve overall flavour of the noodles.

The 1,2-dihydro-2,2,4-trimethyl-quinoline was the major acetone flavour compound found in cooked instant noodles, which gradually increased from T1 to T7. The 4-chlorobutanoic acid was also comparatively found in high levels in T5 to T7. Increasing level of salt (> 1%) in food could affect the butanoic acid content (Wang *et al*., 2012). The 2-furanmethanol, octanol, and 1-hexanol,2-ethyl-(CAS) were the few predominant alcoholic flavour compounds found in cooked instant noodles which increased with the incorporation of SDEW. A decreased alcohol flavour in egg-containing food could be induced by lipid oxidation (Umano *et al*., 1990; Qin *et al*., 2012). The prolonged salting of SDEW had increased the aldehydes such as 3-furaldehyde, benzaldehyde, 2,5-dimethyl-, and decanal in cooked instant noodles. This is in accordance with Harlina *et al*. (2018). Undecane, nonane, 5-propyl, (1-butyloctyl) cyclohexane, tridecane, tridecane-4-methyl, ethane, 1,1'-oxybis (2-ethoxy-), and 1,2-propanediol were few of alkane flavours that were found higher in SDEW-incorporated instant noodles.

The addition of sodium-based alkaline salt source in instant noodle formulation helped in increasing alkaline flavour (Gulia *et al*., 2014). Esters in SDEW-incorporated instant noodles gradually increased as the salting duration increased. For furan flavour, 2-methylfuran gradually decreased with the incorporation of prolonged salting of SDEW in cooked instant noodles. Cysteine is the precursor of 2-methylfuran (Tang *et al*., 2013), and this was adversely affected by prolonged salting (Figure 4B). Ketones, particularly 2,3-butanedione and 4,4-dimethyl-2-(Z-prop-1-enyl)-cyclopentanone were predominant and gradually increased in cooked instant noodles incorporated with SDEW. Propanenitrile, 3-methylbutanenitrile, and 4-methylpentanenitrile were the predominant nitriles observed in cooked instant noodles incorporated with SDEW. Phenols in cooked instant noodles were very minimal, and gradually decreased with the incorporation of SDEW.

Pyrazines such as 2-methyl pyrazine was predominant in cooked instant noodles, and it slowly increased with the incorporation of SDEW. On the

Table 2. Volatile compounds in instant noodles incorporated with salted duck egg white from various salting durations.

Volatile compound	**Treatment**								
(relative concentration, %)	**C1**	**C2**	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**
Acetone									
Quinoline, 1,2-dihyro-2,2,4-trimethyl-	-	27.59 ± 0.01^{c}	28.17 ± 0.02^{b}	28.88 ± 0.04^{b}	28.93 ± 0.02^{b}	29.14 ± 0.01^{ab}	29.86 ± 0.01^{a}	29.93 ± 0.01^{a}	30.17 ± 0.05^{a}
2-hydroxy-2-methyl-4-pentanone	-	0.37 ± 0.01^{e}	0.44 ± 0.01^{d}	0.48 ± 0.03^{d}	0.54 ± 0.08^{c}	0.61 ± 0.07^{b}	0.67 ± 0.01^{b}	0.71 ± 0.01^{a}	0.75 ± 0.02^{a}
Acid									
Butanoic acid, 4-chloro-	-	22.07 ± 0.02^{d}	23.17 ± 0.07^{c}	23.99 ± 0.94^{bc}	24.13 ± 0.27^{b}	24.86 ± 0.65^{b}	24.91 ± 0.11^{b}	25.14 ± 0.15^{a}	25.86 ± 0.03^{a}
Alcohol									
2-methylpropanol	-	2.74 ± 0.03^{b}	2.77 ± 0.03^{b}	2.81 ± 0.07^{ab}	2.83 ± 0.08^{ab}	2.91 ± 0.04^{a}	2.95 ± 0.03^{a}	2.97 ± 0.01^{a}	3.07 ± 0.01^{a}
2-Furanmethanol	-	22.46 ± 0.01^{b}	22.51 ± 0.12^{b}	22.67 ± 0.91^{b}	22.81 ± 0.91^{b}	22.93 ± 0.78^{b}	23.16 ± 0.71^{a}	23.79 ± 0.41^{a}	23.92 ± 0.91^{a}
Cyclohexanemethanol, a-methyl-4-(1-methylethyl)	-	15.4 ± 0.02^{a}	13.17 ± 0.61^{b}	12.58 ± 0.13^{c}	11.44 ± 0.16^{d}	10.08 ± 0.31^{e}	9.67 ± 0.06^{e}	9.13 ± 0.11^{e}	8.56 ± 0.06^{f}
Octanol	-	15.69 ± 0.01^{c}	16.11 ± 0.07^{b}	16.35 ± 0.07^{b}	16.88 ± 0.18^{b}	16.97 ± 0.56^{b}	17.22 ± 0.06^{a}	17.33 ± 0.17^{a}	17.87 ± 0.71^{a}
1-Hexanol,2-ethyl-(CAS)	-	20.03 ± 0.05^{c}	20.18 ± 0.21^{c}	20.57 ± 0.06^{c}	20.88 ± 0.71^{c}	20.93 ± 0.17^{c}	21.81 ± 0.19^{b}	22.14 ± 0.14^{a}	22.56 ± 0.31^{a}
Aldehyde									
Nonanal	-	0.14 ± 0.01^{a}	0.11 ± 0.01^{b}	-	-	-	-	-	-
Benzaldehyde	-	1.65 ± 0.01^{e}	2.02 ± 0.02^{d}	2.81 ± 0.7^{d}	3.33 ± 0.07^{c}	3.87 ± 0.09^{c}	4.47 ± 0.07^{b}	4.91 ± 0.19^{b}	5.16 ± 0.01^{a}
3-Furaldehyde	-	19.64 ± 0.03^{d}	20.11 ± 0.07^{c}	20.18 ± 0.11^{c}	20.87 ± 0.91^{c}	21.18 ± 0.47^{b}	21.83 ± 0.01^{b}	23.11 ± 0.34^{a}	23.96 ± 0.16^{a}
Benzaldehyde, 2,5-dimehtyl-	-	24.36 ± 0.01^{c}	24.49 ± 0.09^{c}	23.27 ± 0.68^{d}	25.83 ± 1.21^{bc}	26.15 ± 0.54^{b}	26.91 ± 0.71^{b}	26.91 ± 0.23^{ab}	27.2 ± 0.71^{a}
Pentanedial	3.54 ± 0.08^{a}	3.17 ± 0.00^{b}	3.17 ± 0.10^{b}	3.06 ± 0.41^{bc}	3.01 ± 0.15^{c}	3.01 ± 0.12^{c}	2.97 ± 0.04^{cd}	2.91 ± 0.02^{cd}	2.77 ± 0.01^{d}
Nonanal	-	18.32 ± 0.04^{b}	18.33 ± 0.31^{b}	18.31 ± 0.73^{b}	18.33 ± 0.78^{b}	18.35 ± 0.97^{b}	18.46 ± 0.24^{a}	18.38 ± 0.23^{b}	18.41 ± 0.18^{a}
Decanal	-	20.22 ± 0.09^{b}	21.14 ± 0.67^{ab}	21.17 ± 0.80^{ab}	21.33 ± 0.19^{a}	21.37 ± 0.17^{a}	21.44 ± 0.14^{a}	21.47 ± 0.2^{a}	21.58 ± 0.05^{a}
Alkane									
Dodecane, 2,6,10-trimethyl-	12.36 ± 0.10^{b}	12.11 ± 0.01^{b}	12.12 ± 0.01^{bc}	11.87 ± 0.71^{c}	11.81 ± 0.56^{c}	10.68 ± 0.83^{d}	16.13 ± 0.41^{a}	9.63 ± 0.32^{e}	9.14 ± 0.14^{e}
Dodecane, 4,6-Dimethyl-	14.58 ± 0.10^{a}	14.33 ± 0.01^{a}	14.17 ± 0.09^{a}	13.96 ± 0.21^{b}	13.55 ± 0.71^{b}	13.11 ± 0.29^{b}	12.87 ± 0.17^{c}	12.66 ± 0.17^{c}	12.13 ± 0.08^{c}
Undecane	-	8.5 ± 0.02^{c}	8.63 ± 0.05^{c}	8.75 ± 0.71^{c}	9.11 ± 0.05^{b}	9.71 ± 0.44^{b}	10.07 ± 0.14^{a}	10.15 ± 0.11^{a}	10.31 ± 0.13^{a}
Nonane, 5-propyl-	-	10.38 ± 0.04^{e}	11.67 ± 0.12^{d}	12.33 ± 0.24^{c}	13.67 ± 0.37^{b}	13.88 ± 0.11^{b}	14.17 ± 0.27^{a}	14.57 ± 0.14^{a}	14.88 ± 0.18^{a}
(1-Butyloctyl) cyclohexane	-	12.83 ± 0.04^{d}	13.88 ± 0.08^{cd}	13.91 ± 0.17^{cd}	14.13 ± 0.89^{c}	14.81 ± 0.59^{c}	15.83 ± 0.09^{b}	16.11 ± 0.05^{a}	16.89 ± 0.12^{a}
Tridecane	-	16.15 ± 0.01^{b}	16.17 ± 0.03^{b}	16.88 ± 0.05^{b}	16.91 ± 0.17^{b}	17.02 ± 0.04^{a}	17.11 ± 0.18^{a}	17.15 ± 0.04^{a}	17.17 ± 0.14^{a}
Tridecane-4-methyl	-	17.5 ± 0.09^{c}	17.67 ± 0.06^{c}	17.81 ± 0.17^{c}	17.93 ± 0.64^{c}	18.13 ± 0.93^{b}	18.37 ± 0.31^{b}	18.36 ± 0.12^{b}	19.01 ± 0.18^{a}
Tetradecane	-	18.51 ± 0.03^{a}	18.34 ± 0.81^{a}	17.67 ± 0.78^{b}	17.11 ± 0.09^{b}	16.56 ± 0.31^{c}	16.44 ± 0.18^{c}	16.31 ± 0.01^{c}	15.88 ± 0.08^{d}
Ethane, 1, 1'-oxybis(2-ethoxy-)	-	18.69 ± 0.01^{a}	18.53 ± 0.14^{a}	18.47 ± 0.86^{a}	18.24 ± 0.81^{a}	18.17 ± 0.23^{a}	18.06 ± 0.17^{a}	17.88 ± 0.08^{b}	17.56 ± 0.17^{b}
1,2-Propanediol	-	21.49 ± 0.20^{c}	21.54 ± 0.28^{c}	21.88 ± 0.13^{c}	22.19 ± 0.12^{b}	22.46 ± 0.19^{b}	22.89 ± 0.14^{b}	23.11 ± 0.31^{a}	23.89 ± 0.28^{a}
Ester									
Hexadecenoic acid, methyl ester	-	28.5 ± 0.40^{c}	29.10 ± 0.14^{b}	30.17 ± 0.91^{a}	29.22 ± 0.21^{b}	27.13 ± 0.13^{d}	26.51 ± 0.16^{e}	26.44 ± 0.41^{e}	25.97 ± 0.16^{f}

Furan									
2-methylfuran	-	0.69 ± 0.00^{f}	0.77 ± 0.01^{e}	0.83 ± 0.01^{d}	0.94 ± 0.06^{c}	1.01 ± 0.01^{b}	1.12 ± 0.01^{b}	1.18 ± 0.05^{b}	2.37 ± 0.04^{a}
2(3H)-Furanone, 5-heptyldihydro	-	14.31 ± 0.06^{a}	13.88 ± 0.04^{b}	13.11 ± 0.37^{b}	12.88 ± 0.17^{c}	12.57 ± 0.32^{c}	12.31 ± 0.10^{c}	11.56 ± 0.07^{d}	11.33 ± 0.41^{d}
Ketone									
2,3-butanedione	4.81 ± 0.20^{e}	3.2 ± 0.04^{f}	7.91 ± 0.09^{d}	8.01 ± 0.21^{c}	8.12 ± 0.28^{c}	8.55 ± 0.08^{b}	8.58 ± 0.11^{b}	8.61 ± 0.056^{b}	8.73 ± 0.07^{a}
5-methyl-2-hexanone	-	0.23 ± 0.01^{a}	0.17 ± 0.07^{b}	0.08 ± 0.00^{c}	-	-	-	-	-
1-phenyl-2-propanone	-	0.18 ± 0.01^{c}	0.20 ± 0.00^{b}	0.23 ± 0.07^{b}	0.27 ± 0.01^{b}	0.29 ± 0.01^{b}	0.34 ± 0.01^{a}	0.37 ± 0.03^{a}	0.38 ± 0.01^{a}
Acetophenone	-	0.23 ± 0.01^{b}	0.23 ± 0.01^{b}	0.21 ± 0.00^{b}	0.22 ± 0.01^{b}	0.24 ± 0.03^{b}	0.23 ± 0.00^{b}	0.23 ± 0.00^{b}	0.34 ± 0.01^{a}
2,3-pentanedione	-	0.23 ± 0.01^{b}	0.23 ± 0.04^{b}	0.25 ± 0.03^{b}	0.27 ± 0.08^{b}	0.28 ± 0.02^{b}	0.33 ± 0.14^{a}	0.35 ± 0.01^{a}	0.35 ± 0.02^{a}
4,4, -dimethyl-2-(Z-prop-1-enyl) --cyclopentanone		11.54 ± 0.07^{d}	12.39 ± 0.31^{c}	12.87 ± 0.34^{c}	13.18 ± 0.78^{b}	13.67 ± 0.18^{b}	13.81 ± 0.19^{b}	13.98 ± 0.07^{b}	14.07 ± 0.17^{a}
Nitrile									
Propanenitrile	-	2.88 ± 0.01^{NS}	2.83 ± 0.01^{NS}	2.83 ± 0.08^{NS}	2.87 ± 0.34^{NS}	2.86 ± 0.01^{NS}	2.83 ± 0.11^{NS}	2.86 ± 0.06^{NS}	2.88 ± 0.08^{NS}
Butanenitrile	-	1.1 ± 0.01^{NS}	1.13 ± 0.04^{NS}	1.13 ± 0.06^{NS}	1.15 ± 0.01^{NS}	1.16 ± 0.03^{NS}	1.18 ± 0.01^{NS}	1.17 ± 0.00^{NS}	1.18 ± 0.01^{NS}
3-methyl butane nitrile	-	4.3 ± 0.05^{d}	4.44 ± 0.01^{c}	4.44 ± 0.19^{c}	4.51 ± 0.31^{c}	4.81 ± 0.01^{b}	4.88 ± 0.05^{b}	4.91 ± 0.08^{a}	4.93 ± 0.03^{a}
Pentanenitrile	-	0.14 ± 0.00^{d}	0.16 ± 0.00^{c}	0.16 ± 0.01^{c}	0.16 ± 0.00^{c}	0.19 ± 0.01^{b}	0.23 ± 0.02^{a}	0.24 ± 0.01^{a}	0.23 ± 0.00^{a}
3-methyl pentanenitrile	-	2.15 ± 0.03^{e}	2.17 ± 0.14^{d}	2.17 ± 0.02^{d}	2.22 ± 0.06^{d}	2.41 ± 0.01^{c}	2.88 ± 0.00^{b}	2.97 ± 0.01^{b}	3.14 ± 0.01^{a}
4-methyl pentanenitrile	-	5.76 ± 0.07^{e}	6.37 ± 0.04^{d}	7.41 ± 0.09^{c}	7.58 ± 0.05^{c}	8.37 ± 0.09^{bc}	8.96 ± 0.16^{b}	9.05 ± 0.04^{ab}	9.55 ± 0.05^{a}
Phenyl acetonitrile	-	0.5 ± 0.01^{a}	-	-	-	-	-	-	-
Phenyl propane nitrile	-	0.78 ± 0.02^{e}	0.88 ± 0.03^{d}	0.89 ± 0.48^{d}	0.93 ± 0.07^{c}	0.97 ± 0.01^{c}	1.01 ± 0.00^{b}	1.08 ± 0.00^{b}	1.28 ± 0.05^{a}
Pyridine									
2-methylpyridine	-	0.41 ± 0.01^{d}	0.61 ± 0.01^{c}	0.61 ± 0.04^{c}	0.68 ± 0.04^{c}	0.73 ± 0.03^{c}	0.84 ± 0.04^{bc}	0.91 ± 0.01^{b}	1.01 ± 0.03^{a}
3-methylpyridine	-	0.14 ± 0.00^{d}	0.13 ± 0.00^{d}	0.18 ± 0.01^{c}	0.21 ± 0.07^{b}	0.24 ± 0.01^{b}	0.27 ± 0.01^{b}	0.33 ± 0.00^{a}	0.37 ± 0.01^{a}
Pyrrole									
2-mehtylpyrrole	-	0.69 ± 0.04^{a}	0.61 ± 0.13^{a}	0.59 ± 0.01^{b}	0.55 ± 0.06^{b}	0.51 ± 0.01^{b}	0.52 ± 0.07^{b}	0.48 ± 0.01^{c}	0.34 ± 0.09^{c}
2,5-dimethylpyrrole	-	0.27 ± 0.01^{d}	0.31 ± 0.00^{c}	0.36 ± 0.06^{c}	0.43 ± 0.09^{b}	0.47 ± 0.01^{b}	0.55 ± 0.01^{ab}	0.59 ± 0.09^{a}	0.61 ± 0.04^{a}
2-ethyl-3,4,5-trimethylpyrrole	-	0.09 ± 0.01^{a}	-	-	-	-	-	-	-
Phenol									
Phenol	-	0.23 ± 0.02^{a}	0.21 ± 0.01^{a}	0.18 ± 0.01^{ab}	0.11 ± 0.01^{b}	0.05 ± 0.00^{c}	-	-	-
Pyrazine									
2-methylpyrazine	-	9.6 ± 0.07^{b}	9.66 ± 0.03^{b}	9.71 ± 0.56^{b}	9.83 ± 0.91^{b}	9.97 ± 0.66^{b}	10.13 ± 0.12^{a}	10.21 ± 0.41^{a}	10.44 ± 0.06^{a}
2,5-dimethylpyrazine	-	1.6 ± 0.03^{d}	1.67 ± 0.04^{d}	1.82 ± 0.02^{cd}	1.93 ± 0.01^{c}	2.01 ± 0.01^{b}	2.22 ± 0.00^{b}	2.34 ± 0.03^{ab}	2.45 ± 0.09^{a}
2,6-dimethylpyrazine	-	1.19 ± 0.04^{d}	1.19 ± 0.02^{d}	2.03 ± 0.07^{c}	2.11 ± 0.03^{bc}	2.17 ± 0.00^{bc}	2.32 ± 0.03^{b}	2.39 ± 0.01^{b}	3.05 ± 0.02^{a}
2-ethylpyrzine	-	0.23 ± 0.01^{a}	0.21 ± 0.01^{a}	0.19 ± 0.01^{ab}	0.11 ± 0.05^{b}	0.05 ± 0.00^{c}	0.05 ± 0.00^{c}	-	-
2,3-dimethylpyrzaine	-	0.23 ± 0.00^{a}	0.11 ± 0.00^{b}	-	-	-	-	-	-
2-ethyl-6-methylpyrazine	-	0.37 ± 0.02^{f}	0.41 ± 0.06^{e}	0.45 ± 0.08^{e}	0.51 ± 0.01^{d}	0.57 ± 0.03^{cd}	0.63 ± 0.01^{c}	0.72 ± 0.02^{b}	0.81 ± 0.01^{a}
2,3,5-trimethylpyrazine	-	0.59 ± 0.06^{g}	0.65 ± 0.03^{f}	0.71 ± 0.09^{e}	0.88 ± 0.08^{d}	0.94 ± 0.08^{c}	1.04 ± 0.00^{bc}	1.16 ± 0.01^{b}	1.27 ± 0.07^{a}

Sulphide/sulphur									
Dimethyl disulphide	-	0.14 ± 0.00^{f}	0.22 ± 0.01^{e}	0.28 ± 0.05^{e}	0.34 ± 0.04^{d}	0.39 ± 0.01^{d}	0.45 ± 0.00^{c}	0.51 ± 0.04^{b}	0.69 ± 0.05^{a}
Dimethyl sulphide	-	0.59 ± 0.02^{e}	0.61 ± 0.05^{d}	0.67 ± 0.06^{d}	0.77 ± 0.07^{c}	0.83 ± 0.08^{b}	0.89 ± 0.01^{b}	0.91 ± 0.01^{a}	0.97 ± 0.01^{a}
Disulphide, di-2-propenyl	-	19.89 ± 0.41^{f}	19.99 ± 0.23^{f}	20.11 ± 0.18^{e}	21.37 ± 0.16^{d}	22.88 ± 0.24^{c}	23.13 ± 0.18^{b}	23.87 ± 0.08^{b}	24.18 ± 0.08^{a}
Methyl mercaptan	-	0.306 ± 0.09^{a}	0.29 ± 0.01^{a}	0.281 ± 0.08^{ab}	0.277 ± 0.07^{ab}	0.263 ± 0.16^{ab}	0.261 ± 0.01^{ab}	0.257 ± 0.05^{ab}	0.249 ± 0.09^{b}
3-methylthiophene	-	0.14 ± 0.01	-	-	-	-	-	-	-
Terpene									
Linalool	-	20.94 ± 0.91^{d}	21.05 ± 0.89^{c}	21.87 ± 0.78^{c}	22.13 ± 0.09^{b}	22.57 ± 0.09^{b}	22.81 ± 0.10^{b}	23.18 ± 0.08^{a}	23.57 ± 0.21^{a}
Thiazole									
1H-Imidazole-4-ethanamine	-	7.74 ± 0.07^{d}	8.04 ± 0.04^{c}	8.13 ± 0.18^{c}	8.56 ± 0.71^{bc}	9.01 ± 0.01^{b}	9.17 ± 0.10^{ab}	9.31 ± 0.03^{a}	9.48 ± 0.30^{a}
4-methylthiazole	-	0.39 ± 0.01^{a}	0.39 ± 0.01^{a}	0.38 ± 0.04^{b}	0.37 ± 0.01^{c}	0.33 ± 0.01^{d}	0.30 ± 0.01^{d}	0.31 ± 0.01^{d}	0.28 ± 0.00^{e}
2-methylthiazole	-	0.96 ± 0.05^{h}	1.16 ± 0.07^{g}	1.88 ± 0.08^{f}	2.12 ± 0.01^{e}	3.17 ± 0.00^{d}	4.66 ± 0.06^{c}	4.89 ± 0.09^{b}	5.13 ± 0.01^{a}
2,4,5-trimethylthiazole	-	0.18 ± 0.01^{a}	0.14 ± 0.01^{b}	0.11 ± 0.03^{b}	0.09 ± 0.00^{c}	-	-	-	-
2(or4)-methyl-4(or2)-propylthiazole	-	0.32 ± 0.04^{a}	-	-	-	-	-	-	-
Thiophene									
2-methylthionphene	-	0.27 ± 0.07^{e}	0.37 ± 0.06^{d}	0.38 ± 0.08^{d}	0.44 ± 0.01^{c}	0.47 ± 0.01^{c}	0.51 ± 0.05^{b}	0.55 ± 0.01^{ab}	0.59 ± 0.01^{a}

Values are mean ± standard deviation (n = 3). Means followed by different lowercase superscripts in the same row are significantly different. NS indicates non-significant. C1: wheat flour (WF); C2: WF ± non-salted duck egg white; T1: WF ± salted duck egg white (SDEW) - 0 d; T2: WF ± SDEW - 5 d; T3: WF ± SDEW - 10 d; T4: WF ± SDEW - 15 d; T5: WF ± SDEW - 20 d; T6: WF ± SDEW - 25 d; and T7: WF ± SDEW - 30 d.

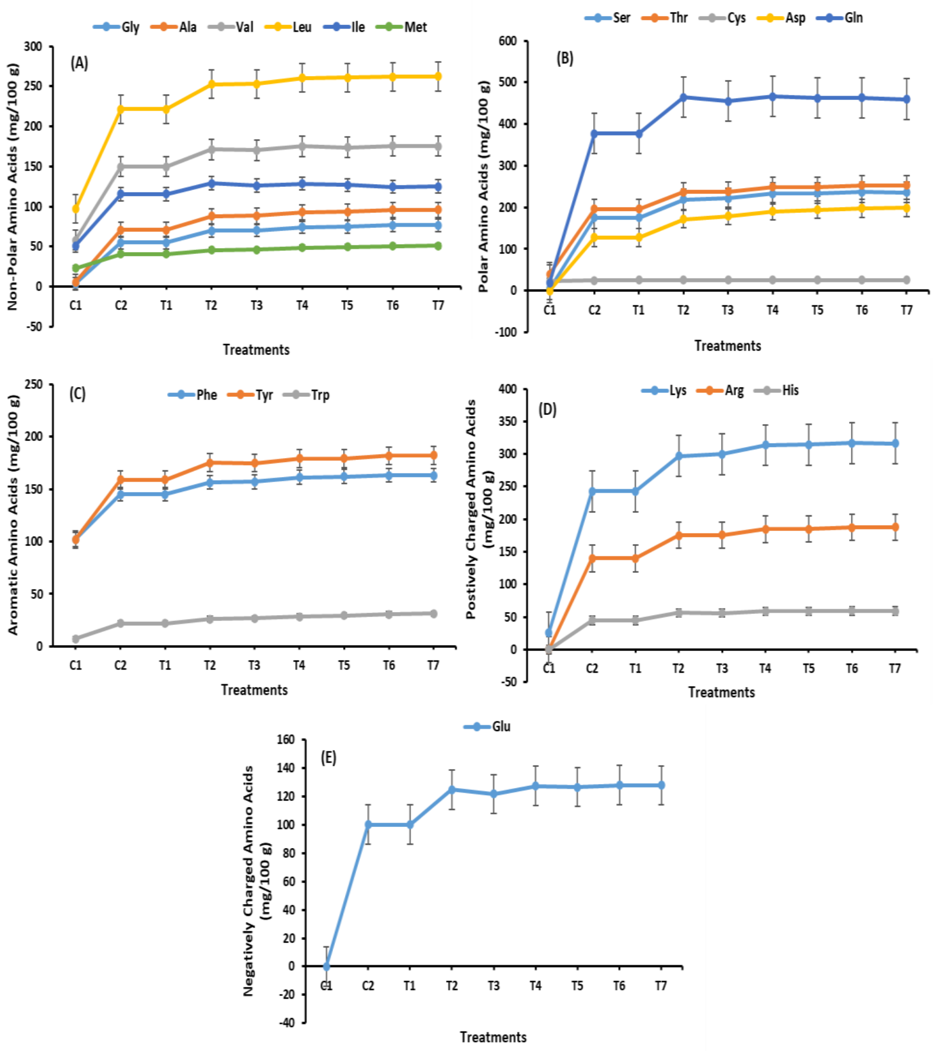

Figure 4. Amino acid compositions [non-polar **(A)**, polar **(B)**, aromatic **(C)**, and positively **(D)** and negatively **(E)** charged amino acids] in instant noodles incorporated with salted duck egg white. C1: wheat flour (WF); C2: WF ± non-salted duck egg white; T1: WF ± salted duck egg white (SDEW) - 0 d; T2: WF ± SDEW - 5 d; T3: WF ± SDEW - 10 d; T4: WF ± SDEW - 15 d; T5: WF ± SDEW - 20 d; T6: WF ± SDEW - 25 d; and T7: WF ± SDEW - 30 d.

other hand, 2-ethylpyrazine and 2,3-dimethylpyrazine were not detected. The 3-methylthiophene was found only in noodles incorporated with DEW, and in the other treatment, it was undetected. Linalool was the only terpene observed in cooked instant noodles, and prolonged salting of SDEW did not adversely affect its level. 1H-Imidazole-4-ethanamine was predominant among the thiazoles found in cooked instant noodles, and it gradually increased with the incorporation of SDEW. SDEW also influenced other flavour compounds such as pyridines, pyrroles, and thiophenes; but their levels found in cooked instant noodles were very minimal.

Amino acid profile

The amino acid profile of cooked instant noodles incorporated with SDEW is shown in Figures 4A - 4E. A total of 19 amino acids [non-polar amino acids (6), polar amino acids (5), aromatic amino acids (3), and positively charged (3) and negatively charged (1) amino acids] were found in cooked instant noodles, and their levels varied with the salting durations of SDEW. Among different treatments, C1, which had only WF, contained very few amino acids (12) particularly Ala, Cys, Gln, Ile, Leu, Lys, Met, Ser, Thr, Try, Tyr, and Val. On the other hand, C2 had all the 19 amino acids, and among them were Arg, Asp, Glu, Ile, Leu, Lys, Phe, Ser, Thr, Tyr, and Val, which were detected at elevated levels. Likewise, the SDEW-incorporated noodles (T1 to T6) had all amino acids as in C2, but prolonging the salting duration of

SDEW had affected the amino acid levels in the cooked instant noodles. As the salting of SDEW was prolonged, the amino acids such as Arg, Asp, Gln, Lys, Phe, Ser, Thr, Tyr, and Val gradually increased from T1 to T7. On the other hand, the content of Cys in cooked instant noodles was very minimal. The amino acids Cys, Met, His, Tyr, and Try were highly susceptible to oxidation and processing conditions, and as a result, only minimal quantities were observed in processed foods. Generally, amino acids are minimal in instant noodles as the wheat flour is the only protein source, and it does not contain much protein (Polpuech *et al*., 2011). The present work had found that the incorporation of DEW and SDEW in the instant noodle compositions could increase the amino acid levels to several-folds. The changes in amino acid levels in SDEW were mainly depended on the degradation of protein during the prolonged salting (Venkatachalam and Nagarajan, 2019).

Sensory evaluation

The most important sensory assessments of fresh cooked and instant noodles are their colour, roughness, stickiness, firmness, and flavour. The sensory evaluation of cooked instant noodles incorporated with SDEW is shown in Figures 5A - 5F. Overall, the results revealed that the incorporation of SDEW in instant noodles significantly improved their quality. There were differences in the sensory results for cooked instant noodles incorporated with

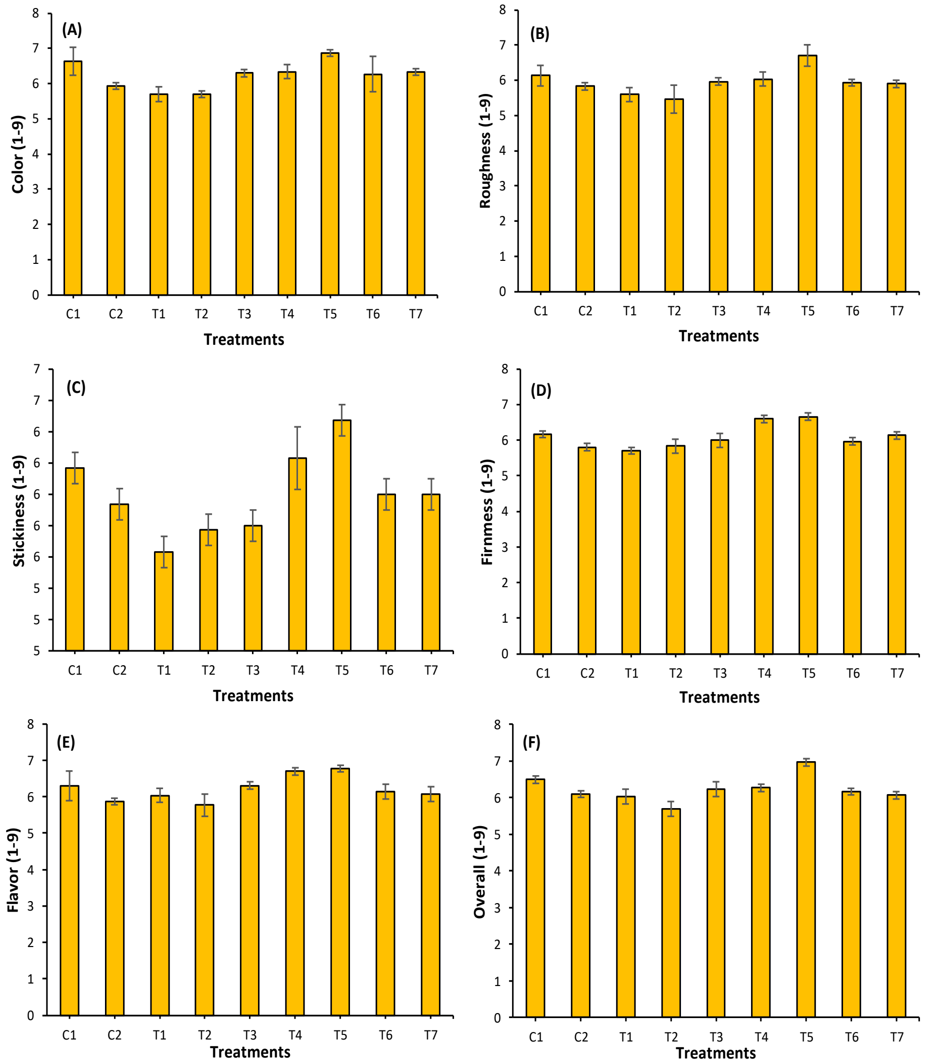

Figure 5. Sensory evaluation [colour **(A)**, roughness **(B)**, stickiness **(C)**, firmness **(D)**, flavour **(E)**, and overall **(F)**] of instant noodles incorporated with salted duck egg white. C1: wheat flour (WF); C2: WF ± non-salted duck egg white; T1: WF ± salted duck egg white (SDEW) - 0 d; T2: WF ± SDEW - 5 d; T3: WF ± SDEW - 10 d; T4: WF ± SDEW - 15 d; T5: WF ± SDEW - 20 d; T6: WF ± SDEW - 25 d; and T7: WF ± SDEW - 30 d.

different SDEW. In Figure 5A (colour), result showed that C1 had slightly higher colour preference than the other treatments. DEW- and SDEW-incorporated instant noodles did not differ much from each other when the salting was minimal, but the trend changed when as salting was prolonged; the colour coordinates were similar from T3 to T7, although T5 has slightly higher scores than the other treatments. The incorporation of eggs could affect the colour characteristics of noodles and influence consumers' acceptance (Hou, 2001). The roughness of cooked instant noodles is shown in Figure 5B. Similar to the colour scores, T5 was slightly rougher than the other treatments. Prolonged salting of SDEW gradually affected the roughness of instant noodles. Stickiness represents the degree to which the noodle sticks to the teeth upon chewing, and is shown in Figure 5C. C1 was slightly stickier than the noodles made with DEW (C2). On the other hand, SDEW-incorporated instant noodles gradually became stickier as the salting reached 20 d (T5), and after that, a sudden decline was observed in T6 and T7. Overall, the firmness of cooked instant noodles did not show significant differences (Figure 5D). The incorporation of egg into noodles slightly improved the stickiness and firmness of noodles (Abe *et al*., 2006; Chang and Wu, 2008). A slight increase in firmness was found in T4 and T5, albeit the differences being small. A similar trend was also observed in the flavour characteristics of cooked instant noodles (Figure 5E). A gradual increase in flavour scores was observed in all treatments, except for T6 and T7. The overall acceptance score slightly differed among all treatments of cooked instant noodles; fluctuation in scores was observed (Figure 5F). Increasing the salting of SDEW did not affect much the consumers' preference of cooked instant noodles. However, the sensory evaluation scores showed that the consumers preferred SDEW salted for 20 d (T5) than the other treatments.

Conclusion

Salted duck egg white is a low-value by-product from salted duck egg yolk preparation, and its value tends to decrease with the duration of salting that causes excessive saltiness of the egg white. The present work revealed a way to successfully use these egg whites in a commercial value-added product, namely instant noodles. The appearance of noodles containing salted duck egg white did not differ much from commercial noodles. The colour coordinates increased with the duration of salting which favourably improved the appearance. The pH of all the samples was in the commercial range. Surprisingly, the cooking yield and optimum temperature was higher for salted duck egg white noodles. Textural properties were better with SDEW, especially in T4 to T7. The free SH and SS groups were higher in salted duck egg white noodles, thus indicating improved physical strength. Salted duck egg white contributed a wide range of flavours to the instant noodles, and increasing level of salting of duck egg white did not significantly affect all flavour compounds, except for some ketones, nitriles, pyrroles, sulphides/sulphurs, and thiazoles. On the other hand, the amino acid profiles were significantly influenced by duck egg white and salted duck egg white in the instant noodles. Wheat flour (C1) control sample without egg white contained very little amino acids as compared to other treatments. The sensory assessment showed no adverse impacts from the incorporation of egg white. Overall, the present work demonstrated that adding salted duck egg white in instant noodle formulations was beneficial; wheat flour and salted duck egg white of 20 d (T5), 25 d (T6), and 30 d (T7) formulations were appropriate for producing instant noodles with improved physical and sensory characteristics.

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References

Abe, Y., Kamifunatsu, Y., Ichikawa, T. and Shimomura, M. 2006. Effect of added egg on the taste and texture of noodles. Journal of Cookery Science Japan 39(5): 289-295.

Adejunwon, H. O., Jideani, O. I. A. and Falade, O. K. 2020. Quality and public health concerns of instant noodles as influenced by raw materials and processing technology. Food Reviews International 36(3): 276-317.

American Association of Cereal Chemists (AACC). 2003. Approved methods of the American Association of Cereal Chemists. 13th ed. United States: AACC.

Asenstorfer, R. E., Appelbee, M. J. and Mares, D. J. 2010. Impact of protein on darkening in yellow alkaline noodles. Journal of Agricultural and Food Chemistry 58(7): 4500-4507.

Association of Official Analytical Chemists (AOAC). 2003. Official methods of the AOAC international. 17th ed. United States: AOAC.

Barrera, G. N., Bustos, M. C., Iturriaga, L., Flores, S. K., León, A. E. and Ribotta, P. D. 2013. Effect of damaged starch on the rheological properties of wheat starch suspensions. Journal of Food Engineering 116(1): 233-239.

Berton, B., Scher, J., Villieras, F. and Hardy, J. 2002. Measurement of hydration capacity of wheat flour: influence of composition and physical characteristics. Powder Technology 128(2-3): 326-331.

Chandra, S., Singh, S. and Kumari, D. 2015. Evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Journal of Food Science and Technology 52(6): 3681-3688.

Chang, H. C. and Wu, L.C. 2008. Texture and quality properties of Chinese fresh egg noodles formulated with green seaweed (*Monostroma nitidum*) powder. Journal of Food Science 73(8): S398-S404.

Choy, A. L., Hughes, J. G. and Small, D. M. 2010. The effects of microbial transglutaminase, sodium stearoyl lactylate and water on the quality of instant fried noodles. Food Chemistry 122(4): 957-964.

Choy, A. L., May, B. K. and Small, D. M. 2012. The effects of acetylated potato starch and sodium carboxymethyl cellulose on the quality of instant fried noodles. Food Hydrocolloids 26(1): 2-8.

Deleu, L. J., Wilderjans, E., Van Haesendonck, I., Brijs, K. and Delcour, J. A. 2016. Protein network formation during pound cake making: the role of egg white proteins and wheat flour gliadins. Food Hydrocolloids 61: 409-414.

Farrand, C., Charlton, K., Crino, M., Santos, J., Rodriguez-Fernandez, R., Ni Mhurchu, C. and Webster, J. 2017. Know your noodles! Assessing variations in sodium content of instant noodles across countries. Nutrients 9(6): article no. 612.

Foo, W. T., Yew, H. S., Liong, M. T. and Azhar, M. E. 2011. Influence of formulations on textural, mechanical, and structural breakdown properties of cooked yellow alkaline noodles. International Food Research Journal 18(4): 1295-1301.

Fu, B. X. 2008. Asian noodles: history, classification, raw materials, and processing. Food Research International 41: 888-902.

Gan, C. Y., Ong, W. H., Wong, L. M. and Easa, A. M. 2009. Effects of ribose, microbial transglutaminase and soy protein isolate on physical properties and *in-vitro* starch digestibility of yellow noodles. LWT - Food Science and Technology 42(1): 174-179.

Gulia, N., Dhaka, V. and Khatkar, B. S. 2014. Instant noodles: processing, quality, and nutritional aspects. Critical Reviews in Food Science and Nutrition 54(10): 1386-1399.

Harlina, P. W., Ma, M., Shahzad, R., Gouda, M. M. and Qiu, N. 2018. Effect of clove extract on lipid oxidation, antioxidant activity, volatile compounds, and fatty acid composition of salted duck eggs. Journal of Food Science and Technology 55(12): 4719-4734.

Hou, G. 2001. Oriental noodles. Advances in Food and Nutrition Research 43: 142-194.

Kaewmanee, T., Benjakul, S. and Visessanguan, W. 2011. Effect of NaCl on thermal aggregation of egg white proteins from duck egg. Food Chemistry 125(2): 706-712.

Kovacs, M. I. P., Fu, B. X., Woods, S. M. and Khan, K. 2004. Thermal stability of wheat gluten protein: its effect on dough properties and noodle texture. Journal of Cereal Science 39(1): 9-19.

Li, C., Lu, Q., Liu, Z. and Yan, H. 2018. Effects of the addition of gluten with different disulfide bonds and sulfhydryl concentrations on Chinese white noodle quality. Czech Journal of Food Sciences 36(3): 246-254.

Marzocchi, S., Pasini, F., Verardo, V., Ciemniewska-Zytkiewicz, H., Caboni, M. F. and Romani, S. 2017. Effects of different roasting conditions on physical-chemical properties of Polish hazelnuts (*Corylus avellana* L. var. *Katalońki*). LWT - Food Science and Technology 77(1): 440-448.

Mine, Y. 2002. Recent advances in egg protein functionality in the food system. World's Poultry Science Journal 58(1): 31-39.

Morris, C. F. 2018. Determinants of wheat noodle color. Journal of the Science of Food and Agriculture 98(14): 5171-5180.

Polpuech, C., Chavasit, V., Srichakwal, P. and Paniangvait, P. 2011. Effects of fortified lysine on the amino acid profile and sensory qualities of deep-fried and dried noodles. Malaysian Journal of Nutrition 17(2): 237-248.

Qin, G., Tao, S., Cao, Y., Wu, J., Zhang, H., Huang, W. and Zhang, S. 2012. Evaluation of the volatile profile of 33 *Pyrus ussuriensis* cultivars by HS-SPME with GC-MS. Food Chemistry 134: 1467-1469.

Raikos, V., Campbell, L. and Euston, S. R. 2007. Rheology and texture of hen's egg protein heat-set gels as affected by pH and the addition of sugar and/or salt. Food Hydrocolloids 21(2): 237-244.

Sozer, N. and Kaya, A. 2003. Changes in cooking and textural properties of spaghetti cooked with different levels of salt in the cooking water. Journal of Texture Studies 34: 381-390.

Tan, T. C., Phatthanawiboon, T. and Mat Easa, A. 2016. Quality, textural, and sensory properties of yellow alkaline noodles formulated with salted duck egg white. Journal of Food Quality 39(4): 342-350.

Tang, W., Jiang, D., Yuan, P. and Ho, C.-T. 2013. Flavor chemistry of 2-methyl-3-furanthiol, an intense meaty aroma compound. Journal of Sulfur Chemistry 34: 1-9.

Umano, K., Hagi, Y., Shoji, A. and Shibamoto, T. 1990. Volatile compounds formed from cooked whole egg, egg yolk, and egg white. Journal of Agricultural and Food Chemistry 38: 461-464.

Venkatachalam, K. 2018. Influence of prolonged salting on the physicochemical properties of duck egg white. Brazilian Archives of Biology and Technology 61: article ID e18180134.

Venkatachalam, K. and Nagarajan, M. 2019. Assessment of different proteases on degree of hydrolysis, functional properties and radical scavenging activities of salted duck egg white hydrolysate. Journal of Food Science and Technology 56(6): 3137-3144.

Venkatachalam, K., Keawpeng, I. and Thongbour, P. 2017. Rheological and functional properties of wheat and green gram composite flours. Carpathian Journal of Food Science and Technology 9(3): 72-82.

Wang, C., Kovacs, M. I. P., Fowler, D. B. and Holley, R. 2004. Effects of protein content and composition on white noodle making quality: color. Cereal Chemistry 81(6): 777-784.

Wang, J., Jin, G., Zhang, W., Ahn, D. U. and Zhang, J. 2012. Effect of curing salt content on lipid oxidation and volatile flavour compounds of dry-cured turkey ham. LWT - Food Science and Technology 48: 102-106.

Wee, M. S. M. and Henry, C. J. 2020. Reducing the glycaemic impact of carbohydrates on foods and meals: strategies for the food industry and consumers with special focus on Asia. Comprehensive Reviews in Food Science and Food Safety 19(2): 670-702.

World Instant Noodles Association (WINA). 2020. Global demand for instant noodles. Retrieved on March 13, 2021 from website: https://instantnoodles.org/en/noodles/market.html

Xu, L., Zhao, Y., Xu, M., Yao, Y., Nie, X., Du, H. and Tu, Y. G. 2017. Effects of salting treatment on the physicochemical properties, textural properties, and microstructures of duck eggs. PLoS One 12(8): article ID e0182912.

Zhao, Y., Tu, Y., Xu, M., Li, J. and Du, H. 2014. Physicochemical and nutritional characteristics of preserved duck egg white. Poultry Science 93: 3130-3137.