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Salt release from yellow alkaline noodles

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Abstract

The “fate” of salt in yellow alkaline noodles was followed by measuring the salt release from yellow alkaline noodles during cooking and mastication. Three types of yellow alkaline noodles were produced; yellow alkaline noodles with salt at 0 (YAN0), 5 (YAN5), and 10% (YAN10) of the flour weight. Salt release during cooking was influenced by the cooking time and salt content of yellow alkaline noodles. Extended cooking resulted in higher loss and low salt yellow alkaline noodles showed a higher percentage loss than those with high salt. Textural, mechanical and structural breakdown properties were in the order: YAN10 > YAN5 > YAN0, with YAN10 being the hardest, chewiest, firmest, and has the highest strength and structural integrity. These findings support that low salt content in yellow alkaline noodles and a more extensive chewing resulted in higher percentage of salt release than high salt yellow alkaline noodles that are chewed less extensively.

Introduction

During noodle making, the amount of salts (sodium chloride) added in the noodle formulation can range between 1–3% of the flour weight, with some hand-made noodles containing up to 8% of salts (Fu, 2008). Salts perform three functions; mainly texture improving, flavour enhancing, and inhibition the growth of microorganisms (Fu, 2008). While it plays an important role in food industry, high levels of dietary sodium have been linked to various health problems related to high blood pressure (hypertension), stroke, hypernatremia, stomach cancer, cardiovascular disease, and kidney disease (He and MacGregor, 2010). Hence, there is a clear need for the food industry to identify technical routes to enable functionality to be modified, flavour to be enhanced, and shelf life to be preserved whilst reducing the concentration of sodium salts and maintaining the consumer experience (Tian and Fisk, 2012).

Sensory studies have shown that the perceived flavour intensity changes with time during eating. Tian and Fisk (2012) showed that the panellist perceived saltiness was correlated with the delivery of salt in the mouth. Morris *et al.* (2009) stated that the salt perception was related to the total overall amount of salt delivered in the mouth. Therefore, information on the salt release from the food matrix during mastication in mouth can shed more insight on the salt perception in foods. However, this information for most food products are not well studied and reported.

As far as we are concerned, only the salt release kinetics from cheese (Jack *et al.*, 1995; Davidson *et al.*, 1998), gels (de Loubens *et al.*, 2011a), potato crisps (Tian and Fisk, 2012), pizza (Guilloux *et al.*, 2013), and bread (Konitzer *et al.*, 2013) have been reported. Salt release from yellow alkaline noodles (YAN) has not yet been studied and reported. The primary objective of this study was to determine the fate of salt in YAN: from salt loss during preparation to salt release in the mouth.

Materials and Methods

Materials

The basic ingredients for noodle preparation (i.e. wheat flour, kansui reagent (9:1 sodium and potassium carbonate), and salt) and commercial YAN (YAN-C) were purchased from a local supermarket (Tesco Extra, Penang, Malaysia). Sodium chloride used for preparation of standard solutions was of analytical grade and purchased from Sigma-Aldrich Corp. (St. Louis, U.S.A.).

Noodle preparation

Formulations for the three types of YAN are shown in Table 1. YAN were prepared using the method described by Yeoh *et al.* (2011). Ingredients for YAN making were incorporated by a mixer (KitchenAid, St. Joseph, USA). The mixture was then

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Table 1. Formulation of YAN samples

Ingredients	Types of noodles[1]		
	YAN0	YAN5	YAN10
Wheat flour (g)	100	100	100
Deionised water (g)	50	50	50
Salt (g)	0	5	10
Kansui reagent (g)	1	1	1

[1] YAN0, yellow alkaline noodles with 0% salt; YAN5, yellow alkaline noodles with 5% salt; YAN10, yellow alkaline noodles with 10% salt.

mixed with speed 1 and the speed was raised up every level for every subsequent min until it reached speed 6. The speed of the mixer was then slowed down level by level for every min and was stopped totally after 10 min. The dough was removed and placed in a plastic bag for resting for 5 min before sheeting with a HP-150F noodle machine (Nanjing Hope Co. Ltd., Jiangsu, China) with an initial gap setting at width 6 (~2.1 mm). One pass was made at this setting, followed by width 5 (~1.9 mm) and 4 (~1.7 mm) for the desired thickness using the noodle machine with the dough sheet being folded between passes to ensure homogeneity. The same machine was used for slitting for the YAN piece to a rectangular shape. YAN produced were coated with a thin layer of flour to avoid them sticking together. YAN were steamed using a domestic steamer for 15 min. After steaming, the YAN were brought to room temperature under a fan before being stored in a polypropylene bag.

Approximation of salt content in uncooked YAN

Salt content was determined according to the method as described by Noort *et al*. (2010) with slight modifications. Sample (15 g) was blended with 300 g of deionised water for 5 min. The blended sample was left for 12 h and then tested for conductivity. The conductivity was measured using SevenMulti S40 conductivity meter (Mettler-Toledo GmbH, Greifensee, Switzerland) calibrated with standard solution of 1,413 µS/cm. The salt concentration (mg/kg NaCl equivalent) was calculated using NaCl standard curve (de Loubens *et al*., 2011a). Working standard solutions were prepared by dilution of stock solution (3,000 mg/kg) to give final concentrations between 10 and 1,000 mg/kg in deionised water. The salt content in raw YAN (g/100 g YAN) was calculated using Eq. (1).

$$\text{Salt content in YAN} = [(C - C_0) \times Z \times F \times 100]/W \quad \text{(Eq. 1)}$$

where, C is the salt concentration of uncooked salted YAN (mg/kg), C_0 the is salt concentration of uncooked YAN0 (mg/kg), Z is the amount of water used in blending (kg), F is the conversion factor of mg to g (10^{-3}), and W is the weight of noodle used in blending (g).

Optimum cooking time of YAN

Optimum cooking time of YAN was estimated based on the time required for the white core in the middle of the YAN to disappear. Determination of optimum cooking time for each YAN was achieved by using AACC method 66-50 (AACC, 2000).

Salt release from YAN during cooking

The cooking method was carried out according to the method of Bui and Small (2007) with slight modifications. Sample (15 g) was cooked at their respective optimum cooking time in a saucepan of boiling deionised water (300 g). The remaining water left after cooking of YAN was transferred into a pre-weighed bottle and cooled down to room temperature after which the conductivity and the corresponding salt concentration were determined. The amount of salt release from YAN after cooking (g/100 g YAN) was determined using Eq. (2).

$$\text{Salt release during cooking} = [(C - C_0) \times A \times F \times 100]/W \quad \text{(Eq. 2)}$$

where, C is salt concentration of remaining water after cooking YAN (mg/kg), C_0 is salt concentration of remaining water after cooking YAN0 (mg/kg), A is the amount of water left after cooking YAN (kg), F is the conversion factor of mg to g (10^{-3}), and W is weight of noodle used in cooking (g).

Textural and mechanical properties of YAN

Texture profile analysis (TPA)

TPA was carried out according to the method as described by Li *et al.* (2013) using texture analyser (Stable Micro Systems, TA-XT Plus, Surrey, UK) fitted with 30 kg load cell. Before analysis, calibration was performed using 5 kg load cell. The settings used were: Mode: Measure force in compression; Trigger Type: auto - 20 g; Pre-Test Speed: 2.0 mm/s; Test Speed: 0.8 mm/s; Post-Test Speed: 0.8 mm/s; Strain: 75%; Interval Between Two Compressions: 1 s. Two cooked YAN strands (70 mm in length) were placed straight, flat and parallel to each other on the centre of heavy-duty platform. A cylindrical probe (diameter 36 mm) was used to carry out two continuous compressions on the cooked YAN strands. From the force vs distance graph, few textural parameters were obtained. This includes hardness (N), adhesiveness (N s), chewiness, springiness, cohesiveness, and resilience.

Firmness test

As stated by Foo *et al.* (2011), firmness test was performed according to Method 16-50 AACC with slight modifications to the setting. The firmness of cooked YAN was measured by using TA-XT Plus Texture Analyser fitted with 5 kg load cell, attached with a light knife blade. Before analysis, calibration was performed using 2 kg load cell. The distance the blade should move was set to be 5 mm. The settings used were: Mode: Measure force in compression; Option: Return to start; Pre-Test Speed: 1.0 mm/s, Test Speed: 0.1 mm/s; Post-Test Speed: 10 mm/s; Distance: 4.98 mm; Data Acquisition Rate: 400 pps. Five cooked noodle strands (70 mm in length) were placed straight, flat and parallel to one another at the centre of the heavy-duty platform, with the cooked noodle strands positioned at right angles to the blade. The peak of the resulting force-time graph indicates the firmness value of the cooked YAN.

Tensile strength and elasticity

Tensile strength and elasticity of cooked YAN strands were calculated based on the methods described by Gan *et al.* (2009) using a TA-XT Plus Texture Analyser fitted with 5 kg load cell. Rig calibration was performed before analysis. The distance that the probe set to move apart was 15 mm. The settings used were: Mode: Measure force in tension; Option: Return to start; Pre-Test Speed: 3.0 mm/s; Test Speed: 3.0 mm/s; Post-Test Speed: 5.0 mm/s; Distance: 100 mm. The sample was tested by winding both ends of the cooked noodle strand around the upper and lower rig arm slot respectively. The width of cooked YAN was measured using a ruler while thickness was measured using a manual micrometer (Mitutoyo, MI 7305, Kawasaki, Japan). The cross-sectional area of a cooked YAN was calculated by multiplying its width with thickness. From the force vs displacement curve obtained, the tensile strength can be calculated and expressed as the maximum force per unit cross-sectional area of the cooked YAN (N/m^2). Tensile strength was calculated as using the following equation:

$$\sigma = F/A \qquad \text{(Eq. 3)}$$

where, σ is the tensile strength (Pa), F is the peak force (N), and A is the cross-sectional area of YAN (m^2). The elasticity was then calculated as:

$$\text{Elasticity modulus} = F/t \times (l_0/[A_0 \times v]) \qquad \text{(Eq. 4)}$$

where, F/t is the initial slope (N/s) of the force-time curve, l_0 is the original length of the YAN between the limit arms (0.015 m), A_0 is the original cross-sectional area of the YAN (m^2), and v is the rate of movement of the upper arm (0.003 m/s).

Multiple extrusion cell (MEC) analysis

MEC analysis was carried out according to the method as described by Li *et al.* (2013) using a TA.XT Plus Texture Analyser fitted with 30 kg load cell. The MEC was attached to the texture analyser with proper alignment and calibration. The probe height was calibrated with a contact force of 200 g and a return distance of 95 mm. The settings of the rest were as followed: Mode: measure force in compression; Option: cycle until count; Count: 20 cycles; Test speed: 10 mm/s; Post-Test Speed: 5 mm/s; Distance: 95 mm; Data Acquisition Rate: 2 pps. The temperature of MEC was maintained at 37°C using a digital heating circulator (Tech-Lab Scientific Sdn. Bhd., Protech HC-10, Selangor, Malaysia). Cooked YAN sample (20 g) was placed in the sample vessel and artificial saliva (10 mL) was added before closing the vessel.

When the piston moves up and down, a force vs time graph was created and the data obtained was then fitted into a single exponential decay equation:

$$w(n) = w_{inf} + w1EXP(-n/n_1) \qquad \text{(Eq. 5)}$$

where, w(n) is the work during each extrusion cycle (n), winf is the work per extrusion after a large (infinite) number of extrusions, w_1 is the contributions to the loss of energies per extrusion, it is a measure for the amount and the strength of YAN structure that has been broken down, and n1 determines the decay rate of the work per extrusion with an increasing number of extrusions.

In vitro salt release experiment

In order to monitor in vitro salt release profile of YAN, MEC analysis was used to breakdown the structure of cooked YAN. Cooked YAN (20 g) was placed in the sample vessel and artificial saliva (10 g) was added before being compressed for a defined number of times (from 1 to 15 cycles), which mimics the action of chewing the cooked YAN in mouth for 1 to 15 times. After the cycle counts, fluid in the sample vessel was collected and diluted 10× with deionised water, after which the conductivity and the corresponding salt concentration were determined. The percentage of salt released into artificial saliva was determined using the following equations:

$$X = [(C - C_0) \times A \times F \times df \times 100] / W \quad \text{(Eq. 6)}$$

$$\%\ \text{Salt released into artificial saliva} = X/(Y - Z) \times 100 \quad \text{(Eq. 7)}$$

where, X is the amount of salt released into artificial saliva (g/100 g YAN), C is the salt concentration in artificial saliva after compression with salted YAN (mg/kg), C_0 is the salt concentration in artificial saliva after compression with YAN0 (mg/kg), A is the amount of artificial saliva added into the sample vessel (kg), F is the conversion factor of mg to g (10^{-3}), df is the dilution factor, W is the weight of noodle placed into the sample vessel (g), Y is the salt content in YAN, and Z is the amount salt released from YAN into water during cooking.

In vivo *salt release experiment*

The chewing and swabbing protocols were performed according to the methods of Tian and Fisk (2012) with slight modifications. A group of subjects (n=10) were recruited from the Food Technology students (Universiti Sains Malaysia) on the basis of their willingness to conduct a repeatable swabbing protocol. They were trained to perform the chewing and swabbing protocol as described below.

Cooked YAN (5 g) were inserted in the mouth and positioned on the rear of the tongue, followed by a defined number of chews (5 or 10 times), and with free tongue movement a bolus was formed (where possible), the timer was then started. The tongue was cleaned by the front teeth and the tongue swabbed (every 10 s for 60 s) with pre-weighed ashless filter papers (Whatman, Maidstone, UK) that had been cut into 2 cm^2 (2 cm × 1 cm) and subsequently placed in pre-weighed centrifuge tubes (50 mL). Isolated saliva samples were then weighed to calculate saliva weight, diluted with deionised water by 1,000× and vortexed for 1 min to make the samples ready for conductivity measurement. Deionised water was used to rinse the mouth between samples, and 10 min was allowed between each sample to clear the palate.

Statistical analysis

Results were expressed as mean values ± standard deviation of three replicates (unless otherwise stated). Analysis of variance (ANOVA) and Duncan's test for multiple comparisons were used for analysing data. SPSS version 20 (IBM Corp., Armonk, U.S.A.) was used to complete the statistical tests.

Results and Discussion

Salt release from YAN during cooking

There were significant ($P<0.05$) differences in conductivity values between the raw YAN samples (Table 2). In general, conductivity was in the order; YAN10 > YAN5 > YAN-C > YAN0. This pattern is expected since YAN10 contained the highest amount of salt compared to other YANs. Thus, the higher the amount of salt added into the YAN, the higher the conductivity values. For YAN0, the conductivity was mainly attributed to the presence of ions from kansui reagent. This value was used as the background to determine the salt content in YAN5, YAN10, and YAN-C using Eq. (1). Even though there was no information on the salt content of YAN-C the amount of salt added into the noodles could be estimated. The value of conductivity suggests that the salt content of the YAN-C was ~1.87 g/100 g YAN (~2.88% of flour weight). This is within the range normally used in noodle formulation, which is between 1–3% of the flour weight (Fu, 2008). Significantly lower ($P<0.05$) conductivity measurements of YAN-C as compared to those of YAN5 and YAN10. This could be due to a lower amount of salt used in YAN formulation or a significant amount of salt leached out during processing of YAN-C. The high recovery (min of 95%) of the salt content from raw YAN shows that the developed method could be used to estimate the salt content in YAN.

It is crucial to cook the noodles at the optimum time because optimally cooked noodles will give an elastic and chewy bite without much sticking and is pleasant for consumption (Miskelly and Moss, 1985). The optimum cooking time for the YAN samples were shown in Table 3. The results obtained were in consensus with previous studies conducted by Fu (2008) and Baik (2010). During the cooking process, the salt released out from YAN into the cooking water may increase the boiling point and decrease the cooking time of the noodles. Therefore, noodles with the addition of salt, i.e. YAN5 and YAN10, will have a shorter cooking time compared to those without the addition of salt, i.e. YAN0 (Dexter *et al.*, 1979).

In general, amount of salt released from YAN into the cooking water was higher in YAN10 than YAN5 (Table 3). This was observed because YAN with more salt added in the formulation will release more charged ions (e.g. Na^+ and Cl^-) into the cooking water, contributes to a higher conductivity measurement and thus higher salt concentration. During the cooking process, there was a considerable amount of salt

Table 2. Conductivity and amount of salt recovered from different types of YAN

Samples[1]	Salt added into the formulation (g/100g YAN)	Conductivity (μS/cm)	Amount of salt recovered (g/100 g YAN)	% Recovery (Accuracy)
YAN0[2]	0	330 ± 4.36^{d}	N.D.	N.D.
YAN5	3.21	3,313 ± 28.87^{b}	3.17 ± 0.03^{b}	99
YAN10	6.21	5,853 ± 11.55^{a}	5.88 ± 0.02^{a}	95
YAN-C	Unknown	1,790 ± 10.12^{c}	1.87 ± 0.01^{c}	Unknown

[1] YAN0, yellow alkaline noodles with 0% salt; YAN5, yellow alkaline noodles with 5% salt; YAN10, yellow alkaline noodles with 10% salt; YAN-C, commercial yellow alkaline noodles.
[2] Conductivity value obtained from YAN0 was due presence of kansui reagent in YAN formulation. N.D. means not determined.
Comparisons within the same column are shown in the table with the data written as mean ± standard deviation of 3 replicates. Means followed by different letter (a–d) are significantly different at P<0.05 level of significance according to Duncan's Multiple-Range Test.

lost from YAN into water. YAN10 shows the lowest percentage of salt lost in cooking water as compared to YAN5. This indicates that YAN prepared with higher amount of salt has a lower tendency to release salt into cooking water during the cooking process. The additions of salt in the formulation of YAN result in the binding of salt ions to the polar sites (peptide bonds and polar amino acids) on the gluten proteins (Chiotelli *et al*., 2004; Abang Zaid *et al*., 2010). This reduces the mobility of salt ions and thus YAN10, which contains the highest amount of salt show relatively lower percentage of salt loss into cooking water than YAN5.

Textural, mechanical properties and structural breakdown analysis of YAN

Results show that different YAN formulation will significantly (P<0.05) affect the textural and mechanical properties of YAN (Table 4), and these were in good agreement with the previous study conducted by Foo *et al.* (2011). Compared with other YAN samples, YAN10 shows significantly (P<0.05) higher textural and mechanical parameters. This indicates that YAN10 was the hardest, chewiest, firmest, and most elastic, as it has the strongest gluten protein network as compared to other YAN samples. However, YAN5 and YAN10 showed similar cohesiveness and resilience, thus they could not be clearly differentiated based on these two parameters. Since YAN10 was the hardest among all YAN samples, hence greater amount of force was required to breakdown the noodles structure.

When the noodles were compressed from an intact structure at the beginning to the level of w_{inf}, the work per extrusion will decrease with a value w_1. Therefore, w_1 is a measure for the amount of strength to break down the structure. The summation of winf and w_1 will result in the value of the work consumed during the first extrusion. On the other hands, n_1 determines how fast the work per extrusion decrease with increased number of extrusions. The smaller the value of n_1, the work per extrusion drops quicker with increasing number of extrusions and the structure are broken down faster.

The meaningful parameters generated from MEC analysis are shown in Table 4. The results obtained show that YAN10 had significantly (P<0.05) higher MEC parameters compared to YAN5 and YAN0 and there were significant (P<0.05) differences in the MEC parameters measured among different YAN samples. In general, Work 1st, w_{inf}, w_1, and n_1 values were in the order: YAN10 > YAN5 > YAN0. This indicates that YAN10, with the highest amount of salt added in the formulation was the highest in structural integrity among all YAN samples. Besides that, YAN10 shows the highest winf value and this reflects that large pieces of particles still remained after an infinite number of extrusions. Hence, more energy was required to force the noodles through the hole of the piston with no further structural breakdown (Foo *et al.*, 2011). In addition, high w_1 and n_1 of YAN10 denotes that more strength was required to cause a collapse in the structures and the structure is broken down at a slower rate than YAN0 and YAN5.

The difference in the textural, mechanical properties and structural breakdown characteristics of YAN samples was influenced by the amount of salt presence in the formulation. When salt was added to the noodle dough, it was able to shield the negative charges on the gluten protein (Galal *et al.*, 1978; Danno and Hoseney, 1982; Alfonso *et al.*, 2002) by the formation of bond between some salt ions and the negatively charged gluten protein. Salt helps to remove the repulsive forces and neutralised the overall charge. Hence, it allows the protein molecules to interact with one another and result in a stronger protein network, which leads to a stronger, tighter, and more compact noodle dough (Galal *et*

Table 3. Optimum cooking time, approximate salt released and percentage of salt lost from different YAN samples into cooking water

Samples[1]	Optimum cooking time (min)	Conductivity of cooking water (S/cm)	Amount of salt released into cooking water (g/100 g YAN)	Salt lost into cooking water (%)
YAN0[2]	4.25 ± 0.1[a]	278.00 ± 1.00[c]	N.D.	N.D.
YAN5	3.50 ± 0.1[b]	2,500.00 ± 15.28[b]	1.90 ± 0.02[b]	60.51
YAN10	3.00 ± 0.1[c]	3,850.00 ± 20.00[a]	3.17 ± 0.02[a]	52.05

[1] YAN0, yellow alkaline noodles with 0% salt; YAN5, yellow alkaline noodles with 5% salt; YAN10, yellow alkaline noodles with 10% salt.
[2] Conductivity value obtained from YAN0 was due to the leaching of kansui reagent from YAN during cooking. N.D. means not determined.
Comparisons within the same column are shown in the table with the data written as mean ± standard deviation of 3 replicates. Means followed by different letter (a–c) are significantly different at P<0.05 level of significance according to Duncan's Multiple-Range Test.

Table 4. Textural, mechanical and MEC parameters of different YAN samples

Parameters	YAN Samples[1]		
	YAN0	YAN5	YAN10
Textural Properties			
Hardness (N)	101.28 ± 0.85[c]	159.17 ± 1.22[b]	203.16 ± 2.26[a]
Adhesiveness (N.s)	294.05 ± 3.94[c]	336.59 ± 7.52[b]	439.92 ± 6.32[a]
Chewiness (N)	51.09 ± 1.79[c]	84.75 ± 7.04[b]	125.85 ± 3.29[a]
Springiness	0.70 ± 0.02[b]	0.73 ± 0.04[b]	0.82 ± 0.05[a]
Cohesiveness	0.76 ± 0.05[a]	0.73 ± 0.02[a]	0.72 ± 0.02[a]
Resilience	0.48 ± 0.04[b]	0.53 ± 0.03[ab]	0.59 ± 0.54[a]
Mechanical Properties			
Firmness (N)	3.87 ± 0.05[c]	4.31 ± 0.08[b]	5.12 ± 0.01[a]
Tensile (kPa)	27.23 ± 0.86[c]	35.80 ± 0.24[b]	47.50 ± 0.67[a]
Elasticity (kPa)	14.96 ± 0.47[c]	25.83 ± 1.28[b]	34.48 ± 2.01[a]
MEC Parameters			
Work 1st (J)	2.42 ± 0.14[c]	3.07 ± 0.12[b]	3.64 ± 0.04[c]
w_{inf} (J)	0.20 ± 0.02[c]	0.28 ± 0.02[b]	0.36 ± 0.01[c]
w_1 (J)	1.05 ± 0.06[c]	1.34 ± 0.07[b]	1.72 ± 0.11[c]
n_1 (J)	0.24 ± 0.02[c]	0.35 ± 0.01[b]	0.43 ± 0.03[c]

[1] YAN0, yellow alkaline noodles with 0% salt; YAN5, yellow alkaline noodles with 5% salt; YAN10, yellow alkaline noodles with 10% salt.
Comparisons within the same row are shown in the table with the data written as mean ± standard deviation of 3 replicates. Means followed by different letter (a–c) are significantly different at P<0.05 level of significance according to Duncan's Multiple-Range Test.

al., 1978; Preston, 1981; Danno and Hoseney, 1982). The strong gluten protein network formed in YAN10 was mainly due by the presence of high amount of salt in the formulation. According to Foo *et al.* (2011), the gluten protein network has a significant effect on the texture of the noodles. Noodles with a stronger protein network and higher dough strength were expected to be harder, firmer and chewier. High dough strength also has a positive relationship with firmness, tensile strength, and elasticity (Miskelly and Moss, 1985) of YAN. Therefore, YAN10 with highest amount of salt added in the formulation had significantly (P<0.05) higher textural and mechanical parameters as compared to other YAN samples.

Salt release from YAN during mastication

During mastication, the physical structure of YAN is ruptured and salt is released into the saliva. Thus, the in vitro and in vivo study on salt content in saliva and YAN allows the observation of the overall

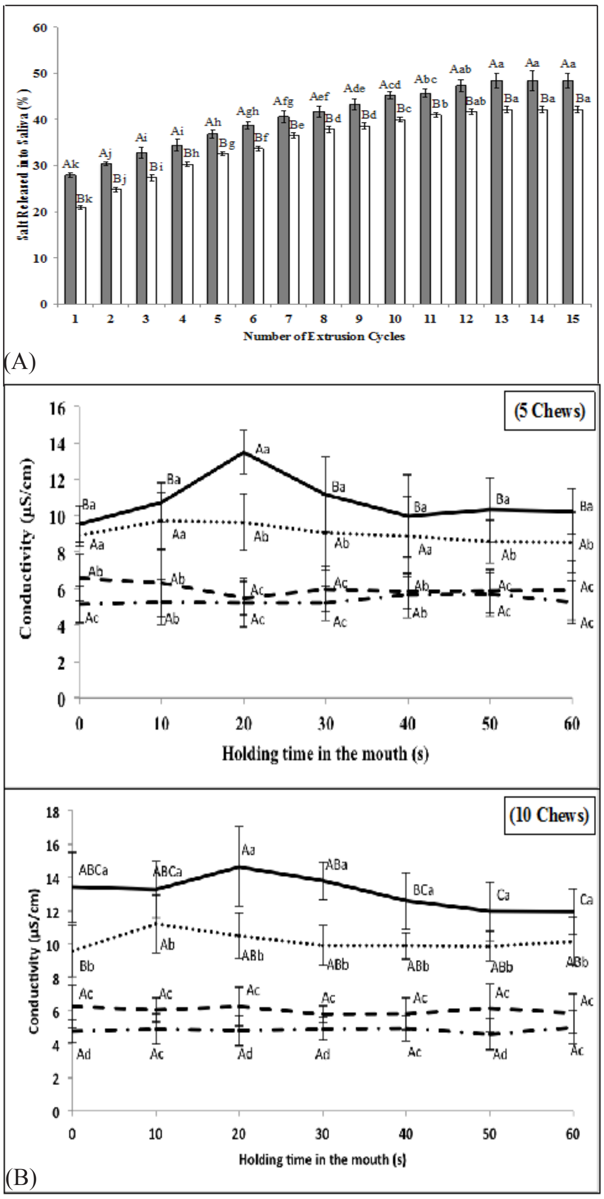

Figure 1. (A) *In vitro* salt release experiment showing percentage of salt released from YAN5 (grey bars) and YAN10 (white bars) into artificial saliva after 1 to 15 extrusion cycles. Error bars indicate the standard deviations of three independent measurements (n=3). Different uppercase superscript letters (A–B) on top of each bar indicate significant (P<0.05) difference between samples for each extrusion cycle. Different lowercase superscript letters (a–k) on top of each bar indicate significant (P<0.05) difference between the numbers of extrusion cycles for each sample. (B) In vivo salt release experiment showing conductivity of YAN0 (– – – –), YAN5 (..................................) and YAN10 (———) with 5 or 10 chewing action by 10 panellists. Conductivity for blank (– . – . –) was used to calculate the salt concentration in saliva. Data points with different uppercase letters (A–C) indicate a statistically significant (P<0.05) difference between the holding times. Means with different lowercase letters (a–d) indicate a statistically significant (P<0.05) difference between samples.

effect of salt release during chewing. These would provide a better understanding of how salt is released during mastication of YAN (Taylor and Hort, 2004; Musteata and Pawliszyn, 2007).

In vitro *study of salt release from YAN*

During *in vitro* study, the structure of YAN strands was broken down by the compression action of MEC that mimics the masticating action in the human mouth. After subjecting both YAN5 and YAN10 to 15 extrusion cycles, the results obtained show that the percentage of salt released into saliva increased (Figure 1A). YAN10 released significantly (P<0.05) lower percentage of salt into saliva during mastication and thus it was able to retain higher amount when compared to those of YAN5. Since the presence of salt is known to enhance the textural attributes of noodles, hence YAN10 with a higher salt content has a stronger, harder and firmer structure that provides higher resistance to structural breakdown as compared to YAN5. This was confirmed by textural, mechanical and MEC analysis (Table 4). Hence, YAN with high salt content has a lower tendency to release the salt during mastication, and thus retained more salt in the noodle structure.

In general, as the number of chews increased, the percentage of salt released into saliva will increase significantly (P<0.05). During mastication, the disintegration of food structure result in an increase in the surface of the food exposed to saliva, and thus promotes the dissolution of taste compounds in saliva (Salles *et al*., 2011; Tom *et al*., 2011). When the number of extrusion cycle increases, the degree of noodle fragmentation increases and this create more contact area between the fractured YAN fragments and saliva. Thus, more salt ions will be released into the saliva and less salt ions was retained in the YAN matrix. This leads to an increase in the concentration of salt in saliva and decrease in the concentration of salt in YAN. However, the increase in the percentage of salt released into saliva plateau at 13 chews and remains constant in further chewing. After 13 chews, the structure of YAN could have been completely breakdown and most of the salt in YAN had been released out into the saliva. Therefore, there was no further increase in the salt released into saliva from 13 chews onwards, and the percentage of salt remaining in YAN was expected to remain constant.

In vivo *study of salt release from YAN*

During *in vivo* study, a relatively low and constant conductivity reading (Figure 1B) was recorded in saliva when chewing was conducted without any YAN (blank). This was due to presence of organic and inorganic substances, including electrolytes (e.g. sodium, potassium, calcium, chloride, magnesium, bicarbonate, and phosphate) and proteins in saliva (Pedersen *et al.*, 2002; Pionnier *et al.*, 2004; de Almeida Pdel *et al.*, 2008). A similar trend could be observed when chewing was conducted with YAN0 even though the saliva conductivity of YAN0 was slightly higher than the saliva conductivity of the blank (Figure 1B). This was due probably to the release of conductive materials in the kansui reagent from the YAN0. Overall, the conductivity was in the order; YAN10 > YAN5 > YAN0 > blank. These observations are expected since YAN10 contained the highest amount of salt compared to other YANs, and that more chewing actions would yield higher release of salt over time. The salt in high salt food is more easily transferred from the matrix into the saliva-receptor interface (Tian and Fisk, 2012).

After 5 and 10 chews, the baseline of conductivity for YAN5 and YAN10 was significantly ($P<0.05$) higher than those of blank and YAN0 (Figure 1B). The conductivity of saliva was higher in YANs that were orally processed with 10 chews compared to 5 chews. After 5 chews, conductivity of YAN5 remained almost constant throughout holding. In contrast, YAN10 showed a peak of conductivity at 20 s holding time. After 10 chews, conductivity of YAN5 and YAN10 showed apparent peaks at 10 and 20 s of holding, respectively. According to de Loubens *et al.* (2011b), the salt release could be affected by the fracture properties and contact area of the food. The greater the contact area of food, the faster the solute release out from the food matrix. In the case of YAN, the 10 chews resulted in more structural breakdown and thus an increase in contact area to facilitate more salt release. After reaching the peak and almost all salt had been released, the conductivity returned to the baseline. This decrease could be due to the dilution of the saliva remaining in the mouth by the saliva flow from salivary gland (de Loubens *et al*., 2011a).

Similar salt release profiles have also been reported in other food samples such as peanuts, cheese, mash potato, and crisps (Davidson *et al*., 1998; Tian and Fisk, 2012). Chewing is thus an important process in oral processing to maximise salt release through structural breakdown to impart saltiness. As many Asian consumers tend to slurp rather than chew the noodles extensively, the salt content and its release properties from YAN may need further investigation.

Conclusion

Longer cooking time caused more salt release from YAN into the cooking water. During cooking of YAN, a large portion (between 52.8 and 73.6%) of salt was leached out from the noodle structure. A lower percentage of salt loss during cooking was observed from YAN with higher salt content. This could be due to the improvement on the YAN structure in the presence of salt, where high salt YAN exhibited higher structural integrity. Results from both *in vitro* and *vivo* salt release experiments show that salt release during mastication was influenced by the chewing action and salt content, whereby low salt YAN and a more extensive chewing leads to a higher percentage of salt release. Holding of a chewed YAN in the mouth for an extended period of time allowed the continued delivery of salt over time. A peak in salt delivery at 10–20 s after chewing was detected in YAN5 and YAN10, but was not found in YAN0 or blank.

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