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Effects of acidification on the extension of shelf life of Japanese wet-type noodles (woo-long noodle)

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Noodles are one of the most important foods worldwide; various methods have been reported to extend their shelf life. In this study, the effects of dipping noodles in various concentrations of acidulant solutions (organic acids) on the shelf life of the noodles were evaluated. The results showed that the growth of the tested microorganisms, that is, *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus*, was significantly inhibited when > 0.5% solutions of acidulants were applied. Here, a 0.5% mixed solution showed a larger halo zone diameter (8.5 to 11.5 nm) than 0.5% citric acid or 0.5% lactic acid solution (8.0 to 9.0 nm). Moreover, six variations of acidulants were used (0.5 and 1% citric acid, lactic acid and their combination), the shelf life at 5°C of the noodles dipped in a 0.5% 1:1 mixed solution for 20 s was also 4 to 6 days longer than those without treatment. All sensory attributes of noodles treated with the mixed solution were the highest (p<0.05) among all the samples. The results of the sensory study also indicated that products treated with the mixed solution had scores that were close to those of untreated noodles, in terms of appearance, texture, taste, hardness and elasticity as well as overall acceptance. Finally, these results provide support for developing a simple method to prolong the shelf-life of fresh noodles and minimizing any negative changes in sensory attributes.

Key words: Acidity, organic acid, antimicrobial agents, microorganisms, sensory evaluation

INTRODUCTION

Noodles are one of the most important foods in Asian cuisine, and the flour used to make noodles in Asia accounts for approximately 40% of the total flour consumed there (Hou and Kruk, 1998). In addition to wheat flour, noodles are made from simple ingredients such as water, salt or alkaline salt and contain carbohydrates, protein and small amounts of fatty acids. Wet-type noodles, such as Chinese yellow alkaline noodle and Japanese white woo-long noodle, are very popular in local market due to their unique mouth-feel and convenience for eating. The most common spoilage organisms in such fresh noodles are bacteria, followed by

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yeast and moulds (Ray, 2001). Due to their high water content, high pH and Aw value, wet raw noodles have a short shelf-life because of microbial spoilage and browning reaction. However, the main problem is that the short shelf life of noodles results in high levels of waste in the industry and may also be a potential source of food poisoning (Ghaffars et al., 2009). Yellow alkaline noodles are partially boiled wet noodles with a pH range of 9.0 to 10.0. Microbial or fungal growth causes the development of sliminess on the surface of noodles at this pH range (Karim, 1989), and thus these noodles are very susceptible to spoilage and have a shelf life of 1 to 2 days. Spoilage is not only due to the visible growth of microorganisms, but also to the production of end metabolites which cause off-odours and slime production (Forsythe, 2000).

In recent years, various methods have been reported to extend the shelf life of noodle products such as free additives. The products are called semi-dried noodles, which ensure both the similar flavour and taste to fresh noodles and a prolonged shelf-life (Li et al., 2016). Irradiation by 10 kGy of 60 Co gamma rays increased the shelf life of fresh noodles to up to 10 days when stored at room temperature (Jianming, 1998). Fu et al. (2008) noted that fresh noodles with neutral pH made using a food grade monolaurin microemulsion system (MMEs) had a shelf life of up to 10 days when stored at 37°C. The addition of *Brevibacterium helvolum* B8 and *Arthrobacter* sp. was attempted as a biological method to increase shelf life; B8 improved the quality of yellow alkaline noodles and extended the shelf life to 7 days (Saito, 2003). Natural antibacterial compounds from lemon extracts and traditional herbs and spices may potentially be useful as food preservatives to improve the microbiological stability of fresh pasta and noodles (Li et al., 2014).

Organic acids, such as citric, malic, acetic, fumaric, tartaric, adipic, lactic, ascorbic acid, etc. have a long history of use as food additives and preservatives for preventing food deterioration and extend the shelf life of foods (Howard et al., 1994). However, little literatures investigated the effects of acidification on the shelf life of noodle products. Many researchers have used organic acid solutions in combination with heat treatment (pasteurization) to increase the shelf life of fresh pasta and noodles (O'Rourke et al., 2003). McGuire et al. (1989) applied hurdle technology, a combination of dough pasteurization, modified atmosphere packaging and chilling to preserve fresh pasta and succeeded in extending the shelf life to 120 days. Li et al. (2011) investigated the effect of water activity, irradiation and their combination on the shelf-life of fresh noodles. It could be extended for more than 7 times by reducing Aw from 0.979 (control) to 0.900 with a combination of humectants including glycerol, propylene glycol, compound phosphate and salt.

To develop a simple method to prolong the shelf-life of fresh noodles and minimize any negative changes in sensory attributes, the present study was therefore, undertaken to determine the best conditions for acidification of woo-long noodles. The effects of dipping noodles in various concentrations of acidulant solutions on the shelf life of the noodles were determined.

MATERIALS AND METHODS

Antibacterial assay

The antibacterial activity of the acidulant solutions was determined according to the methods described by Piddock(1990) with some modifications. The tested microorganisms for the bioassay were *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (BCRC 12606), *Bacillus cereus* (BCRC 14196), which were grown on DC agar or TSA agar or NA agar plates, respectively at 35°C overnight. These plates are referred to as seeded agar. Sensitivity discs (Gram-positive and negative) were used to assay the sensitivity pattern. Eighty microliters of various concentrations of lactic acid and citric acid solution were aseptically pipetted onto the paper discs (Diameter: 8 mm, Advantec), which were placed on individuals plates at 35°C for 24 h. The sensitivity of the tested microorganisms to the acids was indicated by a halo around the discs where no bacterial growth occurred. The diameter of the halo was taken as an index of the degree of sensitivity and was measured with a transparent plastic ruler.

Preparation of noodles

An HK-201 mixer (Hoqurt Co., Ltd.) was used to mix the noodles ingredients and increase the amount of gluten (Moss et al., 1987). The noodle formulation used for all experiments consisted of 100 parts flour, 35 parts water (based on a flour moisture of 11.3%) and 1 part sodium chloride. Sodium chloride was dissolved in the water and added to 300 g of flour in the mixer over 2 min on the slow speed mixing (setting 1). Mixing was continued for 2 min at high speed (setting 2), followed by an additional mixing for 1 min at slow speed. The ingredients were passed through a Chung Hou laboratory noodle machine (Chung Hou Bakery Machine Co., Ltd.) with a gap setting of 1.0 mm. The sheet was folded in two and passed through rollers twice more. The dough was allowed to rest at room temperature in a plastic container for 30 min. The noodle dough was obtained by kneading with conventional roll sheeting and other methods, and was formed into a noodle sheet by sheeting or sheeting/combining. The noodles sheet was folded between passes to ensure its uniformity (Oh et al., 1985). The thickness of the noodle sheet after subsequent maturing between 3 and 6 mm, preferably 5 mm for woo-long noodles (standard noodles) to ensure good viscoelasticity, smoothness, taste and other characteristics (Keiithiro, 2001). The sheet was then cut into noodle strands quickly by pasta machine. To prevent the noodles from sticking together, they were usually coated with a thin layer of wheat flour. The noodles were pre-cooked in boiling water for 2.5 min, with a ratio of at least 1:10 noodles to water (Anon, 1985). The partially cooked noodles were subsequently rinsed with cool tap water and were then ready for further testing.

Process for acidification of noodles

After cooling, the partially cooked noodles were immersed in ten times weight of various concentration of citric acid or lactic acid solution, that is, 0.1% CA or LA, 0.25% CA or LA, 0.5% CA or LA, 1.0% CA or LA, at RT for 20 s. The physical, chemical, cooking and

sensory properties of all treated noodles were analysed.

Chilled storage test

The experimental batches of woo-long noodles were stored at chilled storage (5°C). Storage was continued for 10 days and microbiological testing was performed for each treatment after every day of storage. In addition to estimation of the counts of the tested microorganisms, the total aerobic viable cell counts, were estimated from appropriate dilutions prepared from duplicate packages for each treatment. Total aerobic plate counts were estimated in PCA (casein-peptone-dextrose-yeast agar, HiMedia Laboratories, M091S-500G) after 30°C incubation for 2 to 3 days. In each experiment, two independent packages were tested individually for their microbiological status. The mean values of log colony counts from duplicate plates of relevant dilutions were then given in the tables or plotted in figures.

Analysis of cooking characteristics

Cooking loss

Cooking loss (%) was calculated as described by Lee and others (1998) with some modifications (AACC, 2000; Lee et al., 1998). Distilled water (500 mL) in a beaker was heated on a hotplate until it started boiling. Samples of partial cooked noodles (50 g) were put in the beaker. The noodles were cooked in boiling water for 3 min. The cooking water was poured into a 250-mL volumetric flask; the final volume (500 mL) was then topped off with distilled water. The volumetric flask was shaken to homogenize the cooking water solution. A 20 mL aliquot of the solution was pipette into an aluminum dish, and the sample was dried in an oven at 105°C until a constant weight was obtained. The cooking loss was measured by the following equation below: cooking loss (%) = [dried residue in cooking water (g)/noodle weight before cooking (g)] × 100.

Colour and pH Value

The noodles were analysed for moisture, protein, fat and ash content using standard procedures AOAC (2000). The colour analysis of the partially cooked noodles was performed using a TC-1500 DX spectrophotometer (Tokyo Denshoku, Japan) at ambient temperature. The colorimeter was calibrated by using white and black standards. The colour values $L*$, $a*$ and $b*$ were measured with a C illuminant and a 10° standard observer. The dimension $L*$ indicates lightness, with 100 for white and 0 for black; the $a*$value indicates redness when positive and greenness when negative; and the $b*$value represents yellowness when positive and blueness when negative. The white index (WI) was measured by the following equation: $WI = 100\sqrt{(100-L)^2 + a^2 + b^2}$. The pH of a cooked noodle slurry was measured using a microcomputer pH-VISION 6071 pH meter (JENCO electronics, LTD, NY, USA), which was calibrated using buffered solutions of pH 4.0 and 7.0 (Ng et al., 2011).

Texture analysis

Noodle firmness was measured according to the methods described by Bourne (1978) with some modifications. A TA.XT2 Texture Analyser (Stable Micro System, Surrey, United Kingdom) with 25-kg load cell was used to measure the firmness of cooked noodles. On the basis of preliminary trials, texture parameters were set at pretest speed = 1.0 mm/s; test speed = 1.0 mm/s; post-test

speed = 1.0 mm/s; strain 50%; trigger force Auto-5g; data Acquisition = 200 pps; and adapter No.10. Noodle samples were evaluated within 5 min after cooking. Five strands of cooked noodles were placed parallel to each other on a flat plastic plate. The tensile test was performed, and twelve measurements for each sample were collected.

Shearing force

Five noodle strands with or without acidification were randomly selected and their shearing force was determined with a Sun Rheometer (Model CR-200D, Sun Scientific Co., Ltd. Japan). The parameters were set as follows: test speed: 6 cm/min; compression distance: 15 mm and adapter: No. 10. Twelve data readings were collected for each noodle treatment and all of the data were used in the statistical analysis.

Sensory evaluation

The noodle samples were boiled and cut into 8 cm pieces. The samples weighted 15 to 20 g for each were stored in tightly covered plastic containers, which were kept in a food warmer before testing. The sensory attributes of the cooked noodles were evaluated by 30 panelists consisting of students of the Department of food Technology and Marketing Management, Taipei College of Maritime Technology. All samples were evaluated using a five point hedonic scale, where ''1'' indicated ''dislike very much'' and ''5'' indicated ''like very much''. Each noodle sample was coded with a random set of 3 numbers. The panelists were given drinking water to rinse their mouths before evaluating each sample. The panelists evaluated intensity of noodle colour, roughness, stickiness, firmness, taste, aftertaste, elasticity and flavour.

Statistical analysis

All noodle sample data were analysed with SAS computer software (SAS 2002–2003). An analysis of variance (ANOVA) was conducted to determine the significance of the difference among each of the 3 treatments. Any value that was considered significantly different ($P<0.05$) was subjected to Duncan's multiple range test. The colour and textural characteristics of the noodles were determined at least in triplicate in replicate samples.

RESULTS AND DISCUSSION

The antibacterial activity of various concentrations of CA and LA solutions were examined and judged by assaying the patterns of bacterial sensitivity. Table 1 summarizes the halo zone test results for the tested microorganisms. Based on the diameter of the halo zone, both LA and CA had similar effect on Gram-positive (*Staphylococcus aureus* and *Bacillus subtilis*) and negative bacteria (*E. coli*) tested.

It was found that the combination of CA and LA was more effective, with zones of inhibition ranging from 9.5 to 21.0 mm. The antimicrobial activity of CA and LA against *B. cereus* was slightly lower than against *E. coli* and *S. aureus.* Higher concentration or the combination of CA and LA likely contributed at least in part to the generation of a larger inhibition zone. The mechanism of

Table 1. Inhibitory effect of various concentrations of CA and LA on *Escherichia coli, Staphylococcus aureus* and *Bacillus cereus.*

Test strain	Acid	Concentration (%)			
		0.5	1	3	5
E. coli	CA*	8.5**	10	12	16
	LA	8.5	9	13	15
	CA & LA	9.5	10	13.5	16.5
S. aureus	CA	8	8.5	9.5	16
	LA	8.5	11	12	15
	CA & LA	8.5	9.5	13.5	17.5
B. cereus	CA	9.5	11	17	20
	LA	9	9.5	15	18.5
	CA & LA	11.5	14	18.5	21

* CA: Citric acid; LA; lactic acid; CA & LA: citric and lactic acid (1:1); ** The diameter of the inhibition zone (mm).

Table 2. Cooking loss of the acidified woo-long noodles.

Acid	Concentration (%)				
	0	0.1	0.25	0.5	1
CA*	4.47^{g}** ± 0.21	5.89^{def} ± 0.30	6.19^{cde} ± 0.23	8.31^{a} ± 0.68	8.48^{a} ± 0.25
LA	4.47^{g} ± 0.21	5.86^{def} ± 0.30	6.16^{cde} ± 0.23	7.43^{b} ± 0.55	7.48^{b} ± 0.23
CA & LA	4.47^{g} ± 0.21	5.26^{fg} ± 0.56	5.55^{ef} ± 0.48	6.85^{bc} ± 0.21	6.70^{bcd} ± 0.23

*CA: Citric acid; LA: lactic acid; CA and LA: citric acid and lactic acid (1:1); **[a-g] Mean values with different letters are significantly different (p<0.05); ***Results are mean ±SD of three determinations.

the antimicrobial action of organic acids is not fully understood yet, and activity may vary depending on physiological status of the organism and the physicochemical characteristics of the external environment (Ricke, 2003). Organic acids such as lactic acid are known to inhibit the cell growth and the active uptake of some amino and keto acids into bacterial membrane vesicles in *E. coli* and *B. subtilis* (Doores, 1993). The combination of CA and LA at a final concentration of 0.5% showed a larger halo zone diameter than the same concentration of CA or LA alone, and the diameter of the growth inhibitory zone for CA and LA against *B. cereus* was slightly larger than that against *E. coli* and *S. aureus.*

The proximate composition of the noodles with or without acidification, such as the moisture, protein, fat, ash and carbohydrate contents, were similar to that of commercially available wet noodles in Taiwan in terms of the protein (11.3%), ash (0.4%) and carbohydrate (87.7%) contents. The typical pH value of woo-long noodle from domestic markets in Taipei, Taiwan ranges between 4.12 and 6.58 (marketing survey in this study, data not shown). The pH of the noodles was reduced from 5.79 to 3.84 when treated with different concentrations of acid

solutions. The higher the concentration of acidulants added to the sample, the more the pH value is reduced (data not shown).

According to Shiau and Yeh (2001), the higher the cooking loss, the stickier the noodle surface. Serious cooking loss is undesirable because it means that there was a high starch content in the cooking medium and that the noodles had a low cooking tolerance (Chakraborty et al., 2003). As shown in Table 2, the cooking loss of acidified noodles in this study showed a significant increase (P<0.05) when the concentration of the acid used for the noodle treatment increased. This is especially true for the case of citric acid-treated samples. This result might be due to low dissociation constant of citric acid (Malyniak and Meagher, 1990). Acidification of noodles with 1% CA or LA may affect the sensory properties and texture of the cooked product based on the results of this study.

Shiau and Yeh (2001) indicated that starch gelatinized at 80°C, when its viscosity, elasticity, cutting force and tensile strength increased at high temperature. Once the noodles were cooked, starch gelatinization occurred on the surface of the noodles, contributing to a greater cooking loss (Shiau, 1996). However, the mixture of both

Table 3. Effects of different acid treatments on the colour (L, a, b) and WI values of woo-long noodles.

Acid	Concentration (%)	Colour			
		L	**a**	**b**	**WI**
CA*	0	55.04±1.43^{cd}	− 1.05±0.06^{abc}	10.29±0.4^{bc}	54.85±1.02^{bcd}
	0.10	54.62±1^{d}	− 1.04±0.05^{abc}	11.57±1.63^{a}	53.13±0.99^{c}
	0.25	54.65±1.33^{d}	− 1.04±0.04^{abc}	10.58±1.34^{ab}	53.4±1.24^{c}
	0.50	54.71±0.58^{d}	− 1.1±0.07^{c}	10.1±1.01^{cd}	53.58±0.55^{c}
	1	55.81±1.15^{abc}	− 1.05±0.09^{c}	10.01±1.18^{bcd}	54.66±0.97^{bcd}
LA*	0	55.04±1.43^{cd}	− 1.05±0.06^{abc}	10.29±0.4^{bc}	54.85±1.02^{bcd}
	0.10	55.11±1.06^{cd}	− 1±0.07^{ab}	9.88±0.84^{bcd}	54.17±1.1^{cde}
	0.25	55.13±0.65^{cd}	− 1.09±0.05^{bc}	10.2±0.51^{c}	53.97±0.6^{de}
	0.50	56.25±0.62^{ab}	− 0.99±0.04^{a}	9.12±0.66^{cdef}	55.13±0.74^{abc}
	1	56.52±0.57^{a}	− 1.05±0.09^{abc}	7.81±0.7^{g}	55.82±0.5^{a}
CA and LA*	0	55.04±1.43^{cd}	− 1.05±0.06^{abc}	10.29±0.4^{bc}	54.85±1.02^{bcd}
	0.10	55.38±0.75^{bcd}	− 1.06±0.06^{abc}	10.56±0.99^{ab}	54.13±0.72^{cde}
	0.25	56.35±0.86^{ab}	− 1.06±0.03^{abc}	8.67±0.65^{efg}	55.48±0.94^{ab}
	0.50	56.58±0.82^{a}	− 1±0.11^{ab}	8.47±0.87^{fg}	55.74±0.88^{a}
	1	56.23±0.59^{ab}	− 1±0.06^{ab}	8.81±1.03d^{efg}	55.34±0.47^{ab}

* CA: Citric acid; LA: lactic acid; CA and LA: citric acid and lactic acid (1:1); **Values in the same column with significantly different (p<0.05). ***Results are mean ±SD of three determinations.

CA and LA in equal amounts resulted in lower cooking lost (Table 2). The amount of residue in the cooking water is commonly used as an indicator of the quality of cooked spaghetti and low amounts of residue indicate high pasta cooking quality (Del Nobile et al., 2005). Dick and Youngs (1988) considered cooking loss of 7 to 8% to be acceptable for dried pasta. Additionally, when compared with dried pasta, in this study, cooking losses for all noodles treatments were <8%.

The appearance of noodles is important to consumers, and the colour of the noodles is the most vital quality parameter. The colour of uncooked noodles should be bright and yellow without specks. The colour of the partially cooked noodles with or without acidification was analysed, and the colour was roughly distinguished by eye. The colour of the boiled noodles with or without acidification is presented in Table 3. Their lightness values (L*) was not very different. Beside citric acid, the noodles treated by 0.1 to 1.0% of lactic acid or both have a lightness value (L*) higher than controls, similar to the results described by Shiau (1996). Lactic acid additives can increase lightness values of noodles, and they also show negative values for redness (a*) and low positive values for b*. Decreases in these values as the concentration of the acid use increases are attributed to the presence of natural flavonoid pigments, which are colourless at acidic pH levels but turn yellow at alkaline pH levels (Shelke et al., 1990). As seen in Table 3, the lightness (L*), yellowness (a*), redness (b*) and white

index (WI) did not change significantly (p<0.05), indicating the exterior stability of the noodles. The results also shows that the noodles treated by 0.5% CA & LA has good lightness (L*) and WI values.

In contrast to colour, noodle texture characteristics are more complicated and less understood. The texture of cooked noodles is considered the most critical characteristic in evaluating the quality of noodles and determining consumer acceptance of the product (Bhattacharya et al., 1999). Tensile strength represents the consumption quality of noodles, and it also corresponds to elasticity of the noodles (Chakraborty et al., 2003).

The Japanese preference for woo-long noodle is for a softer, slightly more elastic and adhesive texture. When noodles are cooked, the Japanese woo-long noodle has a significantly different cutting hardness and cohesiveness than Chinese wheat flour noodles, which could be caused by the differences in the protein and carbohydrate composition of the noodles. It is highly likely that woo-long noodle flour is lower in amylase as compared to the Chinese flour. The insoluble glutenin to total protein ratio of Japanese woo-long noodle is higher than the Chinese wheat varieties (Hu et al., 2007).

In this study, the differences in the cooking quality of the noodle after treatments can be attributed to the differences in the acid level of the treatments. Higher concentrations of acidulants significantly decreased (p<0.05) the shearing force of the noodles, as shown in

Table 4. Effects of different acid treatments on the shearing force values of woo-long noodles (n=12).

Acid	Shearing force (mm ^{2}/g)				
	0%	0.10%	0.25%	0.50%	1%
CA	598±70[a]	496±89[ab]	528±77[ab]	473±75[bc]	386±95[c]
LA	598±70[a]	595±39[ab]	589±84[ab]	534±72[ab]	500±57[bc]
CA+LA	598±70[a]	586±89[ab]	581±75[ab]	562±57[ab]	531±39[bc]

*CA: Citric acid; LA: lactic acid; CA and LA: citric acid and lactic acid (1:1); **Results are mean ±SD of three determinations.

Table 4. This was particularly obvious for noodles immersed in citric acid. This result might be due to the action of hydrogen ions or anionic acid residues that cleave the salt linkages of protein molecules, resulting in softer and weaker internal structures as well as molecular binding. Such cleavage might have weakened the protein gluten network as well as the hydrogen binding of the molecules (Tanaka et al., 1967). On the other hand, the increased stickiness and higher cooking loss are likely caused by the diffusion of amylose out from the noodle surface (Shiau and Yeh, 2001).

Commercially available noodle products (domestic market) in Taipei, Taiwan were collected and employed in this study. Microbiological examinations of wet noodles sold in the market showed that woo-long noodles without packaging could be stored for 1 day at 20°C and 3 days at 5°C, respectively. Noodles that were packed and then pasteurized could be stored for 2 to 3 days at 20°C (data not shown). However, depending on the heat resistance of the packaging materials used, products could be stored for 9 days or 1 month longer at 5°C. In terms of woo-long noodles, those subjected to acidification, vacuum packaging and pasteurization at high temperature could be stored at least 3 months with no microbial growth or change in pH value for products at either 5 or 20°C (unpublished data). Samples prepared in the laboratory were evaluated by the chilled storage test. The experimental batches of woo-long noodles were stored at chilled storage at 5°C. Samples of woo-long noodle before and after acidification had similar moisture contents (66.7% and 65.0-68.0%, respectively) and Aw (0.98-0.99) (unpublished data).

As mentioned earlier, the noodles with or without acidification had similar water activities and moisture contents during refrigerated storage with or without acidification. Low pH seemed to impart a bacteriostatic effect on the noodles. In this study, 6 log cfu/g of APC was considered the microbiological quality limit, beyond which the product would be unsuitable for consumption, which is consistent with the limit used by Lee et al. (2001). On any given storage day, the acidified samples had lower APC than the control group. The control, 0.1% CA & LA and 0.25% CA & LA groups exceeded 6 log cfu/g of APC by day 4 (Figure 1). The 0.5% CA and 0.5% LA groups were within this limit after 8 days but exceeded the limit by 10 days (Figure 1). The 0.5% CA & LA and 1%

CA & LA groups did not exceed 6 log cfu/g of APC by 10 days. Thus, in this study, the acidification of noodles (0.5% CA and LA, and 1% CA and LA) increased theshelf life of noodles from 4 to 10 days. During storage at 5°C, the moisture content of both samples (0.5% CA and LA, and 1% CA and LA) declined slowly, and water activity was similar for both samples. Small changes in pH occurred over the 10 days storage, but overall, the changes in pH were very small. Changes in pH can occur in food products as a result of microorganism activity and other chemical reactions. Some microorganisms, such as lactic acid bacteria, reduce the pH by producing acids, and some proteolytic bacteria and mold increase the pH by releasing ammonia from proteins.

The evaluation of the sensory attributes of cooked noodles with or without acidification by a trained panel is shown in Table 5. The sensory evaluation results showed that there were statistically insignificant differences (p >0.05) in the colour, hardness and elasticity among the 0.1, 0.25 (unpublished data), 0.5% and control (0%) groups (Table 5).

The panelists failed to differentiate between the colour of the control and 0.5% (CA + LA). A significant reduction (p<0.05) was also noted in the taste, aftertaste and overall acceptance of the noodles when acidified with 0.5% (CA+LA). All sensory attributes of 0.5% (CA+LA) noodles were rated the best (p<0.05) among all samples; the 1% CA, 1% LA and 1% (CA+ LA) noodles showed the lowest score among all samples in all sensory attributes in the appearance and texture categories. The higher the concentration of CA or LA that was added to the noodles, the less acceptable the noodles were to the panelists. The increase in the acid concentration (1% CA and 1% LA) might have contributed a more sour taste and aftertaste to the noodles as well as to a softer and less elastic texture; these characteristics might not have been favourable to the panelists.

The 0.5% CA treated noodle texture received a viscoelasticity score of 3.18 and smoothness score of 3.32, which were less preferred than the 0.5% (CA + LA) noodles (viscoelasticity score=3.82 and smoothness score=3.64). The overall acceptance of the noodles was in the following order: 1% CA<1% LA<0.5% CA<0.5% LA<0.5% (CA + LA). Generally, acidification by LA may cause a sour, astringent taste. The 0.5% LA noodles received a flavour score of 3.06, so they were less
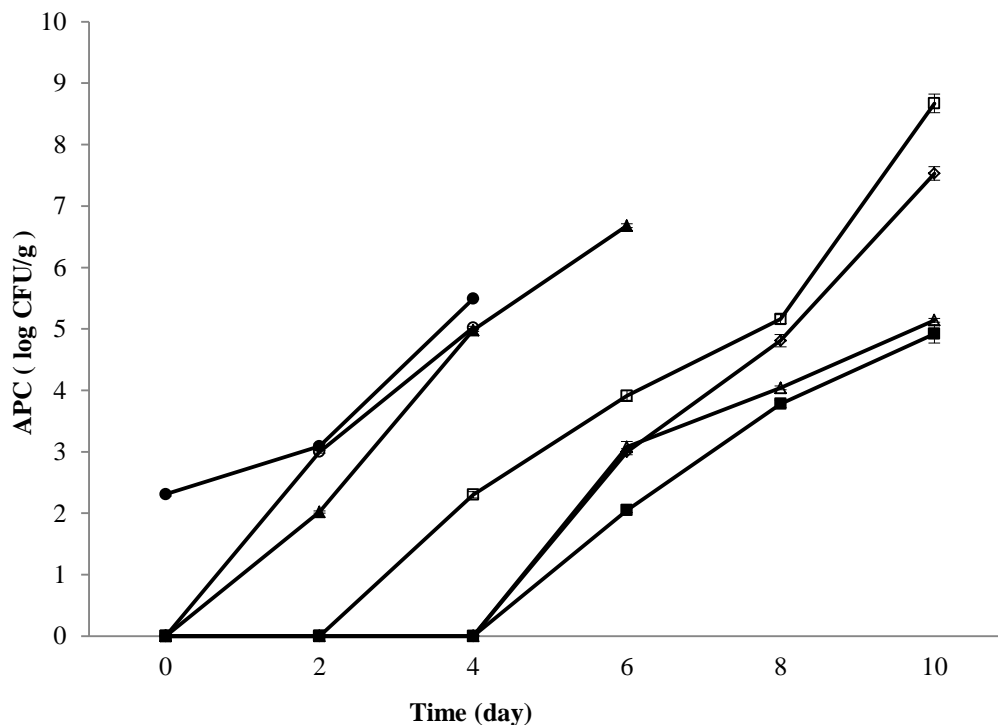
Figure 1. Effects of various combinations of CA and LA on the total bacterial counts of noodles during storage. ●: Control; ○: 0.1% CA & LA; ▲: 0.25% CA & LA; △: 0.5% CA & LA; ■: 1% CA & LA; □: 0.5% CA; ◇: 0.5% LA. Results are mean ±SD of three determinations.

Table 5. Perception of woo-long noodles subjected to different acid treatments.

Acid	Appearance		Texture			Flavour	Total
	Colour	Surface appeal	Hardness	Viscoelasticity	Smoothness		
None	4.32[a**]±0.65	3.90[a]±0.81	3.59[a]±0.73	3.77[a]±0.75	3.59[a]±0.792	3.50[a]±0.74	22.45[a]±3.09
0.5% CA*	4.09[a]±0.64	3.59[a]±0.79	3.36[a]±1.14	3.18[b]±0.96	3.32[a]±0.89	3.50[a]±0.51	21.05[a]±3.169
1% CA	2.20[c]±0.45	3.20[a]±1.64	2.60[b]±1.07	2.60[b]±1.14	2.20[b]±1.30	1.60[b]±0.55	14.40[b]±5.97
0.5% LA	4.05[a]±0.72	3.68[a]±0.89	3.32[a]±1.08	3.41[ab]±1.05	3.32[b]±1.00	3.06[b]±0.66	21.13[a]±3.15
1% LA	2.40[c]±0.89	3.20[a]±1.10	2.80[b]±1.41	2.80[b]±1.00	2.60[b]±1.34	1.40[b]±1.67	15.20[b]±5.02
0.5% CA+ LA	3.91[a]±0.61	3.59[a]±0.67	3.64[a]±0.73	3.82[a]±0.92	3.64[a]±0.66	3.50[a]±0.51	22.05[a]±2.68
1% CA+ LA	3.00[bc]±0.71	3.00[a]±0.71	2.92[b]±0.84	2.40[b]±0.89	2.60[b]±1.14	2.30[b]±1.00	16.32[b]±3.56

*CAL Citric acid; LA: lactic acid; CA and LA: citric acid and lactic acid (1:1); **Values in the same column with different letters are significantly different ($p<0.05$). ***Results are mean ±SD of three determinations.

preferred than the 0.5% CA and 0.5% (CA+ LA) noodles (flavours score 3.50 for both groups). The reduction in the overall acceptability of noodles of 0.5% CA, 0.5% LA and 0.5% (CA + LA) noodles as compared to the control was 21.05, 21.13, 22.05 and 22.45%, respectively. The overall acceptance data showed that the noodles treated with 0.5% (CA + LA) was still accepted by panelists.

Conclusions

In this study, it was found that noodle acidification by immersing in ten times weight of citric acid or lactic acid solution for 20 s could improve the shelf life of noodles. As a result, a 0.5% mixture of solution of 1:1 CA and LA resulted in 4 to 6 days longer shelf life than noodles without treatment. Furthermore, the noodles showed a trend that had statistically insignificant differences ($p >0.05$) in the colour, hardness and elasticity among the 0.1, 0.25, 0.5% and control (0%) groups. Moreover, a significant reduction ($p<0.05$) was also noted in the taste, aftertaste and overall acceptance of the noodles when acidified with 0.5% (CA+LA). However, further studies need to be carried out to determine whether hurdle

technology, using a combination of pasteurization, modified atmosphere packaging and chilling to preserve fresh noodles, could also help to minimize changes of sensory attributes during a long storage period.

Conflict of Interests

The authors have not declared any conflict of interests.

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