Hydrocolloid sour taste control in pasteurized rice

Maria Patricia V. Azanza

Revised: 23 January 2013 / Accepted: 30 January 2013 / Published online: 8 February 2013
© Association of Food Scientists & Technologists (India) 2013

Abstract The effects of kappa (κ)-carrageenan and carboxymethyl cellulose (CMC) in controlling the sourness intensity perception of added acetic, citric, and tartaric acids in solutions for steeping and cooking of rice intended for pasteurization were determined. The rank order of added acids (0.10 and 0.20 %w/v, pH4.00) in the initial development of acidified hydrocolloid solutions was: acetic > citric > tartaric. The final rice acidification protocols included steeping and cooking of *Japonica* rice cultivar *Kanto* in tartaric-acidified hydrocolloid solutions of κ -carrageenan and CMC (0.30 %w/v, 50 ± 2 °C for 1 h) at pH2.75 and 2.90, respectively. The acidified cooked rice in pouches were pasteurized in boiling water (100 °C) to reach 95 °C for 5 min. The pasteurized products were categorized under acidified foods with final $A_w < 0.85$ and pH < 4.00. No perceivable sour tastes from 1 to 12 week storage at 28 ± 2 °C were noted in the pasteurized rice products. The shelf-stable pasteurized products were described as white, translucent, with distinct natural rice aroma and flavor, firm, and slightly elastic mouth and hand feel.

Keywords Pasteurized rice · Hydrocolloid · Sourness perception

Introduction

The shelf-life of cooked rice stored at ambient condition normally lasts only for 1 day. Increasing the shelf-life of cooked rice by thermal processing has been reported to be

possible by sterilization at 121 °C (Reiter et al. 1992; Howard et al. 1994a, b). Unfortunately, concomitant to the increased shelf-life of sterilized rice are changes in sensory characteristics including yellowing of cooked grain, perhaps due to caramelization, and the development of gummy texture with the formation of chalky center during storage at ambient temperature (Krishnamurthy and Siddappa 1965; Sharp et al. 1981; Luh 1991; Howard et al. 1994b). Generally, cooked rice-based products are considered not to be optimally applicable for industrial application due to high rate of retrogradation which significantly shortens the shelf life of the products (Wu et al. 2011).

Cooked rice has the usual pH range of 6.0–6.7 (Center for Disease Control and Prevention 2009). Rice acidification appears to be a good method to lower down the needed heat treatment of cooked rice from sterilization to pasteurization (Howard et al. 1994a, b). However, the sourness of a traditionally accepted low acid rice product makes the resultant acid pasteurized rice commodity unacceptable to its target consumers.

Hydrocolloids have been described as matrix-forming materials that can coat active substances like flavors when in aqueous solution. These substances are quite hydrophilic in aqueous solutions and can exhibit colloidal properties thus applicably called hydrophilic colloids or hydrocolloids (Saha and Bhattacharya 2010). The release and oral perception of such tastants in hydrocolloid solutions are anticipated to be slow by diffusion, thereby, effecting suppressed access to oral receptors of the specific taste (Malkki et al. 1990; Hazen 2003; Troszyńska et al. 2007). The objective of this present study was to determine the effect of hydrocolloids, kappa (κ)-carrageenan and carboxymethyl cellulose (CMC), in controlling the sourness intensity perception of added organic acids: acetic, citric, and tartaric acids in hydrocolloid solutions for steeping and cooking of rice intended for pasteurization.

M. P. V. Azanza (✉)

Department of Food Science and Nutrition, College of Home Economics, University of the Philippines, Diliman, Quezon City, Philippines 1101
e-mail: mpv.azanza@gmail.com

Materials and methods

Rice samples

The rice sample used for the study was *Japonica* cultivar *Kanto* (Kanto, REJ Marketing, Parañaque, Philippines) purchased from a local supermarket. The rice sample was stored at room temperature (28 ± 2 °C) for not more than 1 month. The grain quality parameters of the *Kanto* rice used were: 19.80 % apparent amylose content (AAC), low gel temperature (approximately <70 °C), and gel consistency value of 60 which is between soft and flaky with medium gel consistency (Grain Quality Division, International Rice Research Institute, Los Baños, Laguna, Philippines, May 2011).

Hydrocolloids

The hydrocolloids κ -carrageenan (Marine Resources Development Corporation, Taguig City, Philippines) and CMC (Alyson's Chemical Enterprises, Inc., Quezon City, Philippines) were used in the experiment. The hydrocolloids have a declared shelf-life of 2 years. These were placed in airtight containers and stored in a cool, dry place inside the laboratory at room temperature (28 ± 2 °C) for not more than the declared shelf-life.

Organic acids

Acetic acid (99.88 wt % purity, V.A. and Sons Chemicals, Inc., Valenzuela, Philippines), citric acid (99.70 wt % purity, Alyson's Chemical Enterprises, Inc., Quezon City, Philippines), and tartaric acid (99.70 wt % purity, V.A. and Sons Chemicals, Inc., Valenzuela, Philippines) were the organic acids used. All organic acids were placed in airtight containers and stored in a cool, dry place inside the laboratory at room temperature (28 ± 2 °C) for not more than the declared shelf-life.

Processing of steeping and cooking solutions

Preliminary tests in the processing of steeping and cooking solutions for rice intended for acid pasteurization were done using 0.10 and 0.20 % w/v aqueous solutions of κ -carrageenan and CMC. The hydrocolloid solutions were then acidified by adding 20.0 % (w/v) aqueous solutions of acetic acid, citric acid, and tartaric acid to reach pH4.00. The final concentrations of added acids to reach pH4.00 were calculated. The test acidified solutions were further processed by heating to reach 50 ± 2 °C and cooling immediately to 28 ± 2 °C in a water bath. The pH readings of the cooled processed solutions were determined in triplicates (Eutech pHTestr30, Eutech Instruments Pte. Ltd.,

Singapore). The pH readings of the processed solutions were reported as mean $\pm$ SD of three trials. The preliminary screening of acidified hydrocolloid solutions with organic acids intended for rice steeping and cooking were done to determine the pH stability of solutions after heating to 50 ± 2 °C, which is the temperature to which rice would be steeped. The test solutions were also subjected to sourness intensity perception evaluation.

Sourness intensity perception evaluation of acidified test solutions

The filter paper method described by Ganzevles and Kroeze (1987) was used with modifications to measure the sourness intensity perception of the test steeping and cooking solutions that were prepared. For each test solution, a strip of filter paper (2.00 mm $\times$ 0.60 mm, Whatman #54) was soaked for ≥ 30 s. The soaked filter paper was placed inside a disposable sample cup with lid and the corresponding code for each test solution. Each test filter paper was evaluated within 30 min after it has been soaked in each of the test acidified solution.

A panel of eight females and seven males (18–25 years old) served as evaluators for the sourness intensity perception test. The panelists were instructed to consume a piece of unsalted cracker (SkyFlakes Crackers, Monde M.Y. San Corporation, Philippines) followed by slowly rinsing their mouth with 20 ml distilled water using a sip and spit method at the start of their sourness evaluation and in between each filter paper test. The interval period was maintained at 60 s per filter paper test for each acidified test solution.

After each rinsing procedure, panelists placed pre-soaked filter paper on the left or right side of the frontal part of the tongue using a plastic spoon. The subjects were asked to evaluate sourness intensity perception of the test solutions. The sourness intensity perception ratings were the following: (1) *none*; (2) *very weak*; (3) *weak*; (4) *moderate*; and (5) *strong*. The procedure was done for all test solutions. The results of sourness intensity perception evaluation of the solutions were reported as mean $\pm$ SD of three trials. The initial sourness intensity perception test was done to identify the test organic acid that can be used to effectively depress pH with the least amount of acid needed and with the least perceivable sourness in the succeeding experiments of the study.

Rice acid steeping and cooking

Tartaric acid was selected as the organic acid for further development of hydrocolloid solutions for rice acidification. Acidified hydrocolloid solutions of κ -carrageenan (0.30 %) and CMC (0.40 %) were prepared by adding 20.0 % (w/v) aqueous solution of tartaric acid to further reduce the pH

values to 2.75 and 2.90, respectively. The final concentrations of added tartaric acid to reach the target pH values were calculated. The prepared acidified hydrocolloid solutions were used for the rice acidification.

Commercially available *Kanto* rice cultivar was washed using tap water with a 1:3 rice to water ratio. Rice was washed with adequate grain hand rubbing in tap water for about 1.5 min, followed by draining for 2 min. This washing process was repeated twice. The washed rice was then steeped in the prepared acidified hydrocolloid solutions using 1:1.5, rice to acidified hydrocolloid solution ratio, maintained at 50 ± 2 °C for 1 h. Palm olein oil (Golden Fry Lite, Makati City, Philippines) was then added (0.5 % v/w) to acid-steeped rice which was then boiled at 100 ± 2 °C with the same solution until grains fully absorbed the solution and gelatinized.

The test rice samples were first comminuted using 1:4 rice (g) to distilled water (g) ratio before the pH values were taken (Eutech pHTestr30, Eutech Instruments Pte. Ltd., Singapore). The pH values of the acidified cooked rice were determined and reported as mean $\pm$ SD of three trials.

Sourness intensity perception evaluation of acidified cooked rice

The filter paper method described by Ganzevles and Kroeze (1987) was used with modifications to test the sourness intensity perception of the acidified rice. The acid-steeped cooked rice samples were formed into discs for sourness intensity perception evaluation. Approximately 150 g of acid-steeped cooked rice was placed on top of bamboo mat lined with wax paper. The bamboo mat with rice was rolled to form a cylinder with 2.5 cm diameter. The rice cylinder was cut into 1 cm thick (10 ± 1 g) rice discs. Each piece of rice disc was placed in a coded sample cup with lid for sourness evaluation.

A panel of 9 females and 6 males (15 panelists, 18–46 years old and above) served as evaluators for the sourness intensity perception test of acidified cooked rice. The panelists were instructed to consume a piece of unsalted cracker (SkyFlakes Crackers, Monde M.Y. San Corporation, Philippines) followed by slowly rinsing their mouth with 20 ml distilled water using a sip and spit method at the start of their sourness intensity perception evaluation of the acidified cooked rice sample and in between samples. The interval period was maintained at 60 s per sourness intensity perception evaluation of the acidified cooked rice sample. The panelists were asked to evaluate the coded rice samples presented from left to right. The panelists were asked to place the first sample of rice disc using plastic spoon on the left or right side of frontal part of the panelist tongue then were asked to chew the rice sample eight times (1 chew per 1 s) using the molars while paying attention to

the sourness of masticated rice. The panelists were asked to evaluate sourness intensity perception of the cooked rice samples. The sourness ratings used were the following: (1) *none*; (2) *very weak*; (3) *weak*; (4) *moderate*; and (5) *strong*. The rinsing, chewing, and sourness evaluation procedures were done for all test rice samples. The results for sourness intensity perception were reported as mean $\pm$ standard deviation.

Ambient storage of acid pasteurized rice

The final protocol for rice acidification intended for pasteurization and ambient storage studies utilized κ -carrageenan and CMC hydrocolloid solutions (0.30 % w/v) acidified by adding 20.0 % (w/v) aqueous solution of tartaric acid to reach pH 2.75 and 2.90, respectively. The final concentrations of added tartaric acid to reach the target pH values were calculated. The methods for washing, steeping, oil inclusion, and cooking of *Kanto* rice were done as previously described in rice acid steeping and cooking section of this study. After cooking, the acidified test rice samples were immediately hot-filled (150 g/pouch) in laminated polyethylene terephthalate (PET) 12/nylon15/caspolypolypropylene (CPP) 70 pouches with dimensions 205x100x600mm (Right Pak, San Miguel Yamamura Packaging Corp., Canlubang, Laguna, Philippines). The pouches were sealed and pasteurized in boiling water to reach an internal temperature of 95 ± 2 °C for 5 min.

The acid-pasteurized rice samples in pouches were subjected to pH and water activity (A_w) tests at 0, 1, 3, 4, and 12 week of storage at ambient temperature (28 ± 2 °C). The pH (Eutech pHTestr30, Eutech Instruments Pte Ltd., Singapore) and A_w (Novasina Water Activity Meter Model ms1 Set aw, Novasina, Switzerland) values of the acid-pasteurized rice samples were reported as mean $\pm$ SD of three trials.

A descriptive sensory evaluation was used for the acid-pasteurized test rice samples at 1, 4, and 12 week of storage at 28 ± 2 °C. A panel of three regular rice eaters was asked to evaluate the changes in sensory descriptors in the acid pasteurized rice stored at ambient conditions. The sensory descriptors used to analyze each rice sample were the following: sourness, color, natural rice aroma and flavour, firmness (hand and mouth feel), springiness (hand and mouth feel). The identified sensory descriptors of each rice sample were evaluated using a 5-cm line with the descriptors intensity increasing from 0 to 5 cm.

Statistical data analyses

The results for pH, A_w , and sourness intensity perception evaluations were subjected to one-way Analysis of Variance (ANOVA) with three replications at 5 % level of

significance using SAS Enterprise (Version 2.0.0.417, Copyright (c) 1999–2001 SAS Institute Inc., Cary, NC, USA). Significantly different means ($p < 0.05$) were separated using Duncan's Multiple Range Test (DMRT) at 5 % probability (Lawless and Heymann 1999).

Results and discussion

Sourness perception of acidified hydrocolloid solutions

Table 1 shows the pH and sourness intensity perception of processed acidified hydrocolloid solutions intended for use in rice steeping and cooking that were initially adjusted to pH4.00, heated to 50 ± 2 °C and cooled to 28 ± 2 °C. The preliminary heating of the acidified hydrocolloid solutions was done since steeping of rice was intended to be conducted at 50 ± 2 °C for 1 h. Rice acidification prior to a thermal process may be done through grain steeping and cooking in acidified water (Tollefson and Bice 1972; Howard et al. 1994a, b; Yang et al. 1997).

The rank order of acid concentration added in aqueous hydrocolloid solutions of CMC and κ -carrageenan at 0.10–0.20 % (w/v) to reach pH4 was: acetic acid > citric acid > tartaric acid (Table 1). The strength of an acid is measured by the $-\log$ dissociation constant (pK_a) of acid or its ability to dissociate readily to form hydrogen (H^+) ions in water (Lamond and Pielert 2006) with lower pK_a values assigned to stronger acids (Rubico and McDaniel 1992; Namazian

and Halvani 2006). Tartaric acid was the strongest test organic acid used with pK_a value of 2.96, relative to the lower pK_a values of citric and acetic acids of 3.10 and 4.75, respectively (Wilson and Walker 2010).

The pH values of the heated acidified solutions that were cooled to 28 ± 2 °C generally stayed near pH4.00. The acidified hydrocolloid solutions for both CMC and κ -carrageenan were generally not significantly different in terms of sourness intensity perception ratings at 5 % level of significance. All mean sourness perception ratings of the test solutions at values near pH4.00 have sourness perception $\leq$ very weak sourness except for the hydrocolloid solution containing 0.20 % (w/v) CMC with acetic acid with rating slightly above very weak.

The sourness intensity perception amongst the acidified CMC solutions containing three different organic acids showed that the solutions with tartaric acid were the least sour while solutions with acetic acid was perceived as the most sour. Previous psychophysical and animal physiological studies reported that for a given pH, the sour gustatory stimuli of weak acids like acetic and citric acids were similarly found to be more sour than stronger acids (Ugawa et al. 1998; Ogiso et al. 2000; Lyall et al. 2001; Richter et al. 2003; Lugaz et al. 2005). Weak acids tend to acidify taste cells of the tongue to a greater extent than stronger acids (DeSimone et al. 2001). Undissociated molecules of weak acids in solutions were previously found to more effectively penetrate the lingual tissues during tastings as compared to the fully dissociated protons of stronger

Table 1 The pH and sourness intensity perception of processed solutions of kappa (κ)-carrageenan and carboxymethyl cellulose (CMC) intended for rice steeping and cooking

Hydrocolloid	Concentration of hydrocolloid solutions (%)	Added organic acids	Concentration of organic acid in the hydrocolloid solution (%)	Processed acidified hydrocolloid solution pH*	Sourness intensity perception**
κ -carrageenan	0.10	acetic	0.07	4.08 ± 0.01^a	1.67 ± 0.62^{abc}
		citric	0.05	3.98 ± 0.03^b	1.47 ± 0.64^{bcd}
		tartaric	0.05	3.86 ± 0.03^c	1.67 ± 0.90^{abc}
	0.20	acetic	0.13	4.03 ± 0.02^{ab}	1.27 ± 0.46^{cd}
		citric	0.09	4.00 ± 0.01^{ab}	1.40 ± 0.63^{bcd}
		tartaric	0.08	4.01 ± 0.01^{ab}	1.53 ± 0.74^{abcd}
CMC	0.10	acetic	0.40	3.67 ± 0.03^e	1.47 ± 0.52^{bcd}
		citric	0.18	3.33 ± 0.12^f	1.40 ± 0.63^{bcd}
		tartaric	0.07	4.02 ± 0.04^{ab}	1.07 ± 0.26^d
	0.20	acetic	0.50	3.99 ± 0.05^b	2.07 ± 0.96^a
		citric	0.23	3.75 ± 0.05^d	1.93 ± 0.88^{ab}
		tartaric	0.18	3.60 ± 0.46^e	1.80 ± 0.86^{abc}

a, b, c, d, e, f mean values $\pm$ SD followed by the same letter within a column are not significantly different at 5 % level of significance

*processed acidified hydrocolloid solution pH, initially adjusted to pH4.00, heated to 50 ± 2 °C for 1 h and immediately cooled to 28 ± 2 °C ($n = 3$ trials)

**sourness intensity perception rating: 1 = none; 2 = very weak; 3 = weak; 4 = moderate; 5 = strong ($n = 15$ panelists)

Table 2 The pH and sourness intensity perception of acid-steeped and cooked *Kanto* rice cultivar with hydrocolloid solutions of kappa (κ)-carrageenan and carboxymethyl cellulose (CMC)

Hydrocolloid	Concentration of hydrocolloid solutions (%)	Concentration of tartaric acid in hydrocolloid solution (%) [*]	pH of steeping & cooking solution	pH		Sourness intensity perception of acid-steeped & cooked rice ^{**}
				Raw rice	Acid-steeped & cooked rice [*]	
κ -carrageenan	0.30	0.24	2.75	5.00±0.10	4.01±0.03 ^a	1.33±0.49 ^b
	0.40	0.40	2.75	-	3.93±0.09 ^a	1.73±1.16 ^{ab}
CMC	0.30	0.40	2.90	-	3.93±0.05 ^a	2.00±0.93 ^{ab}
	0.40	0.50	2.90	-	3.75±0.04 ^b	2.33±0.82 ^a

^{a,b} mean values ± SD followed by the same letter within a column are not significantly different at 5 % level of significance

^{*}acid-steeped & cooked rice, acid steeped at 50±2 °C for 1 h and cooked at 100±2 °C to full gelatinization ($n=3$ trials)

^{**}sourness intensity perception of acid-steeped & cooked rice rating, 1=*none*; 2=*very weak*; 3=*weak*; 4=*moderate*; 5=*strong* ($n=15$ panelist)

acids like tartaric acid. The proportional release of more protons from undissociated forms of weak acids directly to the tissue of the tongue acidifies the taste buds to a greater degree than stronger acids during tasting (Lyall et al. 2001; Richter et al. 2003; Neta et al. 2007).

A decrease in sourness intensity perception has been observed as the concentration of acidified κ -carrageenan solutions increased from 0.10 to 0.20 %w/v (Table 1). Decrease in taste intensity perception through the addition of thickeners such as gums and hydrocolloids have been previously reported in studies on the effect of viscosity on the taste intensity of food systems (Moskowitz and Arabie 1970; Pangborn et al. 1978; and Malkki et al. 1990). No apparent masking of sourness perception was observed for acidified CMC aqueous solutions of 0.10 and 0.20 % (w/v). The masking of the sourness perception does not hold true for acidified solutions of CMC at low hydrocolloid concentrations but may be observed at higher concentrations (Christensen 1980).

Acid steeping and cooking of rice

The concentrations of hydrocolloids in solutions were further increased in the succeeding developments of test steeping and cooking solutions using 0.30–0.40 % concentrations with lower target pH values ≤3.00 (Table 2). This was to effectively reduce the pH of solutions without significantly imparting a perceivable sour taste when used for rice acidification. The steeping and cooking solutions used for the rice were initially set at pH2.75 and 2.90 for κ -carrageenan and CMC, respectively. A slightly lower pH was targeted for κ -carrageenan solutions as compared with CMC because it has been observed that κ -carrageenan exhibited more masking of the acid taste.

The *Japonica* rice cultivar *Kanto* was used for this study because it already has a low inherent pH. The results showed that the final pH values of the acidified cooked *Japonica* rice cultivar *Kanto* products using acidified hydrocolloid solutions of 0.30 and 0.40 % (w/v) concentrations were near pH of 4.00. At a final pH level of 4.00 or

Table 3 The A_w and pH of acid pasteurized cooked *Kanto* rice cultivar steeped and cooked with 0.30 % (w/v) hydrocolloid solutions of kappa (κ)-carrageenan (pH2.75) and carboxymethyl cellulose (CMC) (pH2.90) during storage at 28±2 °C

Stored acid-pasteurized cooked rice [*] (wk)	A_w		pH	
	CMC	κ -carrageenan	CMC	κ -carrageenan
0	0.826±0.002 ^{bc}	0.819±0.002 ^c	3.90±0.02 ^b	3.80±0.07 ^b
1	0.812±0.004 ^d	0.827±0.002 ^b	3.80±0.09 ^c	3.80±0.05 ^b
2	0.813±0.006 ^d	0.809±0.005 ^{de}	3.90±0.03 ^b	3.85±0.02 ^b
3	0.829±0.010 ^{ab}	0.806±0.002 ^e	3.95±0.02 ^b	3.95±0.02 ^b
4	0.816±0.005 ^{dc}	0.838 ±0.001 ^a	3.95±0.03 ^b	3.95±0.04 ^b
12	0.826±0.013 ^{bc}	0.815±0.009 ^{dc}	3.95±0.02 ^b	3.92±0.02 ^b

^{a, b, c, d, e} mean values±SD followed by the same letter within a column are not significantly different at 5 % level ($n=3$)

^{*}stored acid-pasteurized cooked rice packed (150 g) in laminated polyethylene terephthalate (PET) 12/nylon15/caspolypolypropylene (CPP) 70 pouches, pasteurized at 95±2 °C for 5 min

less, the acidified cooked rice products were safely placed within the high acidified food category under the guidelines of 21CFR 114 (U.S. Food Drug Administration 1979).

The sourness perception ratings of the acid-steeped and cooked rice samples with acidified κ -carrageenan solutions (pH2.75) were between none to very weak (Table 2). *Kanto* rice steeped and cooked with acidified CMC solutions generally have higher sourness intensity perception and lower final pH values. It has been reported that the acidic environments are suitable for the release of the insoluble free acid forms of CMC at pH<3.00 (Nussinovitch 1997; Imeson 2010). The CMC in aqueous solutions at low pH have been reported to form cross-links through lactonization between carboxylic acid and free hydroxyl groups (Kästner et al. 1997; Chaplin 2011).

Generally, the pH values of the steeped and acidified cooked *Kanto* rice that utilized the acidified hydrocolloid solutions all resulted to cooked grains with pH near 4.00. It was however observed that at 0.40 % (w/v) concentration of the test hydrocolloid solutions, the resultant steeping and cooking solutions already became too viscous that it could possibly interfere with the acidification process. Therefore, 0.40 % hydrocolloid solutions were not used in further development of the solutions intended for acidified rice pasteurization.

Adding palm olein oil at 0.5 % concentration (vol oil/wt rice) after acid steeping was done to minimize cohesion of cooked grains. Previous works on the development of shelf-stable rice also involved oil or emulsifier inclusion to prevent cohesion or formation of solid mass of grains (Tollefson and Bice 1972; Howard et al. 1994a, b; Yang et al. 1997 and Meyer et al. 2000). Oil added after acid steeping may coat the surfaces of the rice which can prevent the cooked grains from sticking and lumping together (Meyer et al. 2000).

Acid-pasteurization of rice at ambient storage

Table 3 shows the results of the extended shelf-life studies at 28 ± 2 °C used for *Jasponica* rice *Kanto* cultivar that was steeped, cooked and pasteurized in acidified hydrocolloid solutions (0.30 %w/v) with initial pH of 2.75 and 2.90 for κ -carrageenan and CMC solutions, respectively. The study was able to utilize pH and A_w as two hurdles which allowed the utilization of pasteurization process instead of using more severe sterilization treatment for the procedure. The pH values of acid-pasteurized rice were recorded to maintain pH $\leq$ 3.95 after 12-wk storage at 28 ± 2 °C. The A_w values of the acid steeped, pasteurized, and stored acid-pasteurized rice products were maintained at $\leq$ 0.839 after 12-wk storage.

Acid pasteurized *Kanto* cultivar with CMC and κ -carrageenan both at 0.3 %w/v incorporations and stored at 28 ± 2 °C for 12 week were found to have the following

sensory characteristics: no perceivable sourness, white color, translucent grains, firm and elastic texture based on both hand feel and mouth feel evaluations. Diminishing distinct natural rice flavor was established during the 12-wk test storage of the acidified pasteurized products.

Conclusions

In the screening of acidified κ -carrageenan and CMC solutions for use in the steeping and cooking of rice intended to be pasteurized, it was established that it is better to use the stronger acid tartaric acid than the weaker acids acetic and citric acids as acidulants for hydrocolloid solutions (0.10 and 0.20 %w/v). The rank order of concentrations of acids added to the solutions to reach pH4.00 was: acetic acid > citric acid > tartaric acid. The study observed that weaker acids in aqueous solutions generated higher sourness perception than stronger acid in solution during tastings. The final rice acidification protocols developed included steeping and cooking of *Japonica* rice cultivar *Kanto* in tartaric-acidified hydrocolloid solutions of κ -carrageenan and CMC (0.30 %w/v, 50 ± 2 °C for 1 h) at pH2.75 and 2.90, respectively. The acid pasteurization of rice at 95 °C for 5 min established shelf stable products for 12 week at ambient storage (28 ± 2 °C) with final pH<4.00 and A_w <0.85. The acid pasteurized rice products developed were under the acidified foods classification based on the guidelines of 21 CFR 114 of the U.S. Food Drug Administration (1979). No perceivable sourness from 1 to 12 week of storage at 28 ± 2 °C was noted in the pasteurized products.

Acknowledgements The author acknowledges the assistance of Ms. Jennibeth F. Paglinawan, Ms. Judit C. Alday, Ms. Maria Lorina C. Morales and Ms. Ma. Elisa V. Obille of the Department of Food Science and Nutrition, College of Home Economics, University of the Philippines Diliman, Quezon City, Philippines.

References

- Center for Disease Control and Prevention (2009) Microworld, In: Health Practices on Cruise Ships: Training for Employees Transcript. <http://www.cdc.gov/nceh/vsp/training/videos/transcripts/microworld.pdf>. Accessed January 7, 2013.
- Chaplin MF (2011) Water Structure and Science. <http://www.lsbu.ac.uk/water/>. Accessed July 22, 2011
- Christensen CM (1980) Effects of solution viscosity on perceived saltiness and sweetness. *Attention, Perception and Psychophysics* 28(4):347–353
- DeSimone JA, Lyall V, Heck GL, Feldman GM (2001) Acid detection by taste receptor cells. *Respiration Physiology* 129(1–2):231–245
- Ganzevles PGJ, Kroeze JHA (1987) The sour taste of acids. The hydrogen ion and the undissociated acid as sour agents. *Chem Senses* 12(4):563–576

- Hazen C (2003) Secrets of Masking Flavors, In: Food Product Design. Virgo Publishing LLC. <http://www.foodproductdesign.com/articles/2003/11/secrets-of-masking-flavors.aspx?pg=3>. Accessed August 8, 2011.
- Howard JG, Atherton J, Field ES, Hawkins MJ (1994a) Shelf-stable rice products. US Patent 5:308–632
- Howard JG, Atherton J, Field ES, Hawkins MJ (1994b) Shelf-stable rice products and processes for their production. US Patent 5:312–639
- Imeson A (ed) (2010) Food stabilisers, thickeners and gelling agents. Blackwell Publishing Ltd., Sussex, UK
- Kästner U, Hoffmann H, Dönges R, Hilbig J (1997) Structure and solution properties of sodium carboxymethyl cellulose. *Colloids Surf A: Physicochem Eng Asp* 123:307–328
- Krishnamurthy N, Siddappa GS (1965) Canning of rice. *J Food Sci Technol* 2:132–153
- Lamond JF, Pielert JH (eds) (2006) Significance of tests and properties of concrete and concrete-making materials. ASTM International, West Conshohocken, PA
- Lawless HT, Heymann H (1999) Sensory evaluation of food: Principles and practices. Aspen Publishers Inc., Gaithersburg, MD
- Lugaz O, Pillias AM, Boireau-Ducept N, Faurion A (2005) Time-intensity evaluation of acid taste in subjects with saliva high flow and low flow rates for acids of various chemical properties. *Chem Senses* 30(1):89–103
- Luh BS (1991) Canning, Freezing and freeze-drying of rice. In: Luh BS (ed) *Rice: Production and utilization*. Avi Publishing, Co., Westport, CT, pp 147–176
- Lyall V, Alam RI, Phan DQ, Ereso GL, Phan TH, Malik SA, Montrose MH, Chu S, Heck GL, Feldman GM, DeSimone JA (2001) Decrease in rat taste receptor cell intracellular pH is the proximate stimulus in sour taste transduction. *Am J Physiol Cell Physiol* 281(3):1005–1013
- Malkki Y, Heinio RL, Autio K (1990) Influence of oat gum, guar gum and carboxymethyl cellulose on the perception of sweetness and flavor. *Food Hydrocolloids* 6(6):525–532
- Meyer PP, Halden PJ, Jaelminger G, Ehrenberg E (2000) Full moisture shelf stable rice product. United States Patent 6:139–898
- Moskowitz HR, Arabie P (1970) Taste intensity as a function of stimulus concentration and solvent viscosity. *J Texture Stud* 1(4):502–510
- Namazian M, Halvani S (2006) Calculations of pKa values of carboxylic acids in aqueous solution using density functional theory. *J Chem Therm* 38(12):1495–1502
- Neta ERC, Johanningsmeier SD, Drake MA, McFeeters RF (2007) A chemical basis for sour taste perception of acid solutions and fresh-pack dill pickles. *J Food Sci* 72(6):352–359
- Nussinovitch A (1997) Hydrocolloid applications: Gum technology in the food and other industries. Blackie Academic and Professional, London, UK
- Ogiso K, Shimizu Y, Watanabe K, Tonosaki K (2000) Possible involvement of undissociated acid molecules in the acid response of the chorda tympani nerve of the rat. *J Neurophysiol* 83(5):2776–2779
- Pangborn RM, Gibbs ZM, Tassan C (1978) Effect of hydrocolloids on apparent viscosity and sensory properties of selected beverages. *J Texture Stud* 9(4):415–436
- Reiter HJ, Frisch D, Scherer B, Covert CA (1992) Acid-stabilized food products. WO1992/08361
- Richter TA, Caicedo A, Roper SD (2003) Sour taste stimuli evoke Ca^{2+} and pH responses in mouse taste cells. *J Physiol* 547(2):475–483
- Rubico SM, McDaniel MR (1992) Sensory evaluation of acids by free-choice profiling. *Chem Senses* 17(3):273–289
- Saha D, Bhattacharya S (2010) Hydrocolloids as thickening and gelling agents in food: a critical review. *J Food Sci Technol* 47(6):587–597
- Sharp RN, Sharp CQ, Kattan AA (1981) A new method for thermally processed canned rice. *Food Technol* 35(5):75–76
- Tollefson CI, Bice CW (1972) Method of preparing canned cooked rice. US Patent 3 647 486
- Troszyńska A, Narolewska O, Wolejszo A (2007) Effect of hydrocolloids on perception of bitterness and astringency in model system. *Polish J Food and Nutr Sci* 57(3A):143–146
- Ugawa S, Minami Y, Guo W, Saishin Y, Takatsuji K, Yamamoto T, Tohyama M, Shimada S (1998) Receptor that leaves a sour taste in the mouth. *Nature* 395:555–556
- U.S. Food Drug Administration (1979) Code of federal regulations title 21 Part 114 Acidified Foods. U.S. Department of Health and Human Services, USA
- Wilson K, Walker J (eds) (2010) Principles and techniques of biochemistry and molecular biology, 7th edn. Cambridge University Press, NY
- Wu Y, Lin QL, Chen ZX, Wu W, Xiao HX (2011) Preparation of chitosan oligomers COS and their effect on the retrogradation of intermediate amylose rice starch. *J Food Sci Technol*. doi:10.1007/s13197-010-0210-2
- Yang AA, Druz LL, Berman T (1997) Process for making shelf-stable ready-to-eat rice. US