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Effects of Fortified Lysine on the Amino Acid Profile and Sensory Qualities of Deep-Fried and Dried Noodles

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ABSTRACT

Introduction: Lysine fortification of wheat flour has been used toward reducing protein energy malnutrition in developing countries. **Methods**: The feasibility of fortifying instant noodles with lysine was evaluated based on sensory qualities and the residual lysine content. Fifty grams of deep-fried and dried instant noodles were fortified with 0.23 and 0.21 g lysine, respectively. The production temperatures used for deep-frying were 165-175°C and for drying, 80-105 °C; these are the temperatures used in the industrial production of both kinds of noodles. Lysine fortification was then performed at the local factories using the commercial production lines and packaging for both types of instant noodles. Both fortified and unfortified deep-fried and dried instant noodles were stored at 50°C under fluorescent light for 2 and 4 months, respectively. **Results**: The fortified products were tested for residual lysine content and sensory qualities as compared with unfortified noodles. The results show fortified products from the tested processing temperatures were all accepted. After storage, significant losses of lysine were not found in both types of noodles analysed. The lysine-fortified noodles had amino acid scores of 102% and 122%, respectively. After 2 months, the sensory quality of fortified deep-fried noodles was still acceptable; however, the dried noodles turned to an unacceptable dark colour. **Conclusion**: This study shows that it is feasible to fortify deep-fried instant noodles with lysine, though lysine fortification exhibited an undesirable colour in the dried instant noodles after storage.

Keywords: Fortification, instant noodles, lysine, sensory quality

INTRODUCTION

Instant noodles were first produced in Japan in 1958 and have become popular among people around the world, both in developed and developing countries. According to a 2008 survey, it was found that the annual consumption of instant noodles in the world averaged about 94 billion cups (World Instant Noodles Association, 2008). The consumptions of instant noodle per capita varies among countries, ranging from 0.57 - 5.54 kg (approximately 10-100 packages) (MOST, 2005); however, these figures tended

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to increase every year. Instant noodles are normally consumed by people of all socio-economic status, which means that undernourished people are consuming it as well.

Instant noodles mainly consist of wheat flour whose protein quality is not sufficient to provide adequate essential amino acids (Tongpun, 2006). Lysine is known to be a limiting amino acid in wheat flour. Without lysine, it is difficult for the body to synthesise protein, hormones, enzyme and antibodies, which are needed for growth, tissue repair and other functions. (Flodin, 1997). Several clinical trials to improve protein quality of wheat flour by adding lysine have been undertaken in Pakistan and China. The people of these countries routinely consume wheat flour as their staple food. It was found that the nutritional and immunological status of the populations have significantly improved with the consumption of lysine-added wheat flour (Hussain *et al.*, 2004; Zhao *et al.*, 2004).

It is purported that the nutritive value of instant noodles, especially protein quality, could potentially be improved by fortifying with lysine. However, this essential amino acid is also the most reactive to the Maillard reaction (Yoshida, 1990), which could cause change in products' acceptability as well as residual lysine. The objective of this study was to evaluate the feasibility of fortifying two popular types of instant noodles in Thailand, that is, deep-fried and dried with lysine.

METHODOLOGY

Amino acid profile of commercial instant noodles and lysine fortification

Noodles and seasoning powders of commercial instant noodle products include 4 brands of deep-fried products. They are Mama™ brand, pork flavor and Oriental kitchen™ brand (Thai President Foods (Public) Co., Ltd., Cholburi, Thailand), Waiwai™ brand (Thai Preserved Food Factory Co., Ltd., Nakhonpathom, Thailand), Yumyum™ brand (Wan Thai Industry Co., Ltd, Bangkok, Thailand), and 1 brand of dried product, Myojo™ brand (Thai President Foods (Public) Co., Ltd., Rayong, Thailand). All product samples were analysed for amino acid profiles. Lysine used in the present fortification was L-lysine monohydrochloride (from BASF (Thai) Co., Ltd., Bangkok, Thailand). The fortification was calculated based on the amino acid requirement of the Food and Agriculture Organization, World Health Organization and United Nations University (FAO / WHO / UNU) for preschool children (2-5 years) of body weight 15 kg (FAO / WHO, 1991).

Effect of processing temperature on sensory qualities of the fortified products

Instant noodles were prepared by using all-purpose wheat flour (Kite™ brand from United Flour Mill Public Co., Ltd., Samutprakan, Thailand), guar gum, sodium tripolyphosphate, sodium acid pyro-phosphate, sodium bicarbonate, potassium carbonate, salt, deionised water and lysine (Taeteang, 1996; Kounhawej, 2005). All ingredients, except wheat flour, were mixed until homogeneous and then mixed with the wheat flour in an electric mixer (Kitchen Aid™ brand Model 5KPM50, St. Joseph, MI, USA) until dough was formed. The dough was then kneaded, sheeted and cut into strips of about 1.0 mm wide by using a noodle making machine ATLAS 150 (Marcoto, Italy). The noodle strips were steamed for 2 minutes in a steamer at atmospheric pressure until starch became partially gelatinised.

The deep-fried instant noodles were produced by showering the steamed noodle strips with salt brine (60 g salt in 900 ml water) and then placed in a drilled stainless steel noodle block mould. The mould containing noodles of 69 g were deep-fried in palm oil (Kasorn™ brand from Patum Vegetable Oil Co., Ltd., Pathumthani, Thailand) at 165, 170 and 175°C for 45 seconds. The deep fried noodles were laid on a stainless steel screen for 30 seconds to remove excess oil, and cooled at room temperature for 30 minutes before being packed in clear plastic bags.

The dried noodles were produced by placing the steamed noodle strips of 77 g in drilled paper block size 10 x 10 cm and dried in a hot-air oven (Binder™ FED series, Germany) at 80ºC, 95ºC and 105 °C for 90 minutes. The dried noodles were then cooled at room temperature and packed in clear plastic bags.

The lysine-fortified products prepared from different processing temperatures were tested for their sensory differences ('Difference from Control Test') from the unfortified products that were prepared at 170°C and 95°C for the deep-fried and dried products, respectively. If the outcome from the 'Different from Control' test was significant, the products were then further testing for sensory acceptability by consumer evaluation.

Shelf-life study

The products used for shelf-life study were industrially produced according to the usual production processes. Production on an industrial scale was done in the production lines of the Thai President Foods (Pubic) Co., Ltd. at Cholburi and Rayong provinces, Thailand for deep-fried and dried types, respectively.

L-lysine monohydrochloride was first dissolved in the alkaline solution, and the the alkaline solution was mixed with the wheat flour in a mixer for 15 minutes until dough formation occurred. The dough was then sheeted and cut into noodles of wavy form. Noodle strands were then cut and packed in a mould and steamed in a tunnel. For the deep-fried type, the steamed noodles were sprayed with soup stock and fried in palm oil for approximately 1 minute at 165 – 175°C. For the dried type, the steamed noodles were dried under hot air for 30 minutes at 85 - 95°C. After frying or drying, they were cooled and packed using commercial packaging.

The finished products were incubated under fluorescent light at 50ºC for 2 and 4 months for deep-fried and dried noodle types, respectively. At 1- and 2-month intervals, the deep-fried and dried products were sampled for analyses of chemical, colour, and sensory properties, respectively. Proximate analysis of noodle blocks was performed only at the end of the shelf-life study. Fortified instant noodle products were tested for sensory acceptability compared to the unfortified noodles.

Colour analysis

The instant noodle samples were ground in a kitchen blender before the measurements took place. Colour was analysed by using Spectro-Colorimeter Model JJ 555 with tungsten halogen lamp as the light source. (Colour Techno System Corporation, Tokyo, Japan) as L* (0 $\rightarrow$ 100, black $\rightarrow$ white), a* (+ $\rightarrow$ -, red $\rightarrow$ green) and b* (+ $\rightarrow$ -, yellow $\rightarrow$ blue).

Lysine analysis

Lysine was analysed by using ninhydrin method, a modification of the Friedman method (Peace & Gilani, 2005; Sun, Lin & Weng, 2006). The ground sample was boiled in ninhydrin solution which consisted of 2 g ninhydrin (APS, Australia) and 0.3 g hydrindantin (Acros Organics, NJ, USA) in a solution of 75 ml dimethyl sulfoxide (Fisher Scientific UK Ltd., UK) and 25 ml lithium acetate buffer. After boiling for 15 minutes, the mixture was cooled in water and added with 50% ethanol. The mixture was filtered through Whatman™ filter paper no. 1. The filtrate was measured for absorbance at 570 nm on a spectrophotometer (Shimadzu, UV-1700 UV-Visible spectrophotometer). In order to avoid interference, both fortified and unfortified noodles of the same shelf-life were analysed. Residual lysine content was determined by subtracting lysine content in unfortified noodles from the fortified ones.

Amino acid profile analysis

The samples were hydrolysed by heating 6 N HCl at 110 °C for 22 hours before being analysed for amino acid profile on high performance liquid chromatography (HPLC). The HPLC system consisted of a 2475 multi-fluorescense detector, and a temperature control module. A Waters Alliance 2695 chromatography manager™ was used to control the system and collect data. Eluent A consisted of AccQ-Tag while Eluent B was a mixture of 60% acetonitrile in water (v/v) with 0.01% acetone. The separation was performed on a 4 μmAccQTag™C_{18}column (150 x 3.9 mm), to which had been injected 5μl of the derivatives. The column temperature was controlled at 37 ± 1 °C at a flow rate of 1.0 ml per minute; the separated amino acid was detected on UV detector at 248 nm (Hong *et al.*, 1995).

Sensory analysis

Sensory qualities of unfortified and fortified instant noodle products were evaluated at the sensory science laboratory in an air-conditioned individual booth by untrained panelists. They were faculty, staff and graduate students at the Institute of Nutrition, Mahidol University.

Sample preparation

Deep-fried instant noodle blocks were cooked in boiling water at the ratio recommended on the label, until done , then immediately spread on an ice bath (stainless steel tray laid over with crushed ice) for 2 minutes in order to minimise overcooking of noodles. Then, weights of cooked noodles and cooked water were determined, and more water was added to compensate the evaporated water. This was done to imitate the manner in which deep-fried instant noodles are normally prepared for consumption, that is, soaking in hot water. In the case of dried instant noodles which normally require boiling, no water was compensated. The water used for cooking was then added with seasoning powder and heated in a double boiler by maintaining the temperature of the soup at 80°C. For serving, ¼ cup of the cooked noodles (approximately 15 g) was portioned into a white melamine bowl (3.5 in, diameter), to which was added h ¼ cup of the soup which resulted in an equilibrium temperature for serving at about 50°C. Panelists were asked to rinse their mouth with plain water before tasting the next sample.

Difference from Control test

The extent of difference from the control was used for evaluating the difference between unfortified and fortified noodle blocks from the lab-scale production. Subjects were asked to determine to what extent the samples differed from the unfortified sample on a 9-point scale (1, extremely lighter than reference; 5, no difference from reference; 9, extremely darker than reference). Samples which were coded with 3-digit random numbers including fortified products and the unfortified products (internal control) were served with the unfortified product that was labeled as 'R'. Twenty untrained panelists involved in this test were asked to judge the differences twice. If the results from the 'Difference from the Control' were significant, the samples were then tested for sensory acceptability.

Acceptability test

The noodle blocks from the lab-scale production that were coded with 3-digit random numbers were informally tested for their sensory acceptability on general appearance and colour suitability by using a 9-point hedonic scale (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely) and a 5-point just-about-right scale (colour: 5 = too dark, 3 = just-about-right, 1 = too light), respectively. The test was performed by 24 untrained panelists.

Table 1. Amino acid profiles of noodle blocks (mg in 1 pack of 50 g) of different brands of instant noodles commercially available in the market

Amino acids	*Brands of instant noodles*				
	Mama™	*Myojo™*	*Waiwai™*	*Oriental Kitchen™*	*Yumyum™*
Ileu[1]	255	180	160	165	195
Leu[1]	485	345	315	335	360
Lys[1]	130	85	86	90	100
Met + Cys[2,3]	115.5	128	115.5	115.5	115.5
Phe + Tyr[1]	510	315	325	355	370
Thr[1]	200	130	135	130	150
Tryp[2,3]	35.5	39	35.5	35.5	35.5
Val[1]	290	195	185	185	225

[1] Results from analysis.

[2] Results from the database for instant noodle block of Nutrition Division (Ministry of Public Health, 1990)

[3] Values for Myojo™ brand were adjusted for moisture and fat contents from the data base for deep-fried instant noodle block of Nutrition Division, Department of Health, Ministry of Public Health, Thailand (no database available for dried type instant noodles)

After being cooked, the noodle samples from industrial production were similarly tested; however, tests on flavour acceptability were also included. The tests were performed by 50 untrained panelists. The sample was served to each panelist by monadic sequence in randomised order.

Statistical analysis

Statistical analysis of the data was performed using a Statistical Package for Scientific Student (SPSS) for WINDOWS version 13.0 (Sabine & Brian, 2004). During storage, significant differences ($p \leq 0.05$) of a treatment at different periods was evaluated by using analysis of variance (ANOVA) and Duncan's test for physical and chemical properties, while ANOVA and Tukey's test were used for sensory qualities of the products. Independent *t*-test was used for testing the significance of the difference ($p \leq 0.05$) between unfortified and fortified products.

RESULTS AND DISCUSSION

Amino acid profile and score of commercial instant noodles

Table 1 indicates that all instant noodles available in the market have a similar amino acid profile, while lysine could be slightly higher in some brands. This might be related to the type of wheat flour used in the production since protein content is a requirement for instant noodle quality of both Thailand's Food and Drug Administration (Thai FDA) and the Thailand International Standards Institute (TISI) (Taeteang, 1996). Wheat flour that contains more protein should have higher lysine content, as well (Anjum, Ahmad & Butt, 2005). An instant noodle industry might want to comply to a higher standard (TISI standard) by using wheat flour with a higher protein content. In some cases, lysine content was lowered due to the use of other flours that were not a source of protein such

Table 2. Amino scores (%) of the deep-fried and dried unfortified instant noodles of the selected brands before and after addition of seasoning powder

Amino acid	*Deep-fried*[1]		*Dried*[2]	
	Without seasoning	*With seasoning*	*Without seasoning*	*With seasoning*
Ileu	104.3	112.8	124.8	133.4
Leu	87.1	95.6	101.5	110.0
Lys	26.7	34.1	28.5	35.8
Met + Cys	84.3	95.5	99.4	110.6
Phe + Tyr	94.1	116.2	97.1	119.1
Thr	72.5	83.7	74.2	85.5
Tryp	58.9	69.3	68.8	79.2
Val	96.5	106.3	108.2	118.0

[1] Waiwai™ brand
[2] Myojo™ brand

as modified starch in Myojo™ brand dried type instant noodles.

Besides lysine, tryptophan was also low with amino acid scores of about 58.91 and 68.82 % (Table 2). However, it was not only wheat that provided amino acid in instant noodles but also seasoning powder. As both noodles and seasoning powder were combined, lysine was still lacking but the requirement of tryptophan could be fulfilled up to 69.27 and 79.18 %. In order to improve protein quality of instant noodle products, lysine fortification was therefore required. In the present study, the fortification was based on the lowest lysine content found in commercial instant noodles (Myojo™ brand for dried and Waiwai™ brand for deep-fried) and aimed to fulfill up to 100% of the amino acid score.

From the calculation, deep-fried and dried noodles should be fortified with lysine at 42.49 and 41.50 mg/g protein, which would result in 232.85 and 213.73 mg lysine/serving based on % protein of deep-fried and dried noodle blocks at 10.96 and 10.30%, respectively (Taeteang, 1996).

Effect of processing temperatures on qualities of instant noodles

Table 3 indicates that the 'Difference from Control' scores of the colours of the fortified noodles that were prepared from different temperatures were significantly different from the colours of the unfortified products that were prepared based on normal production temperatures ($p \leq 0.05$). Subjects were able to detect the darker colour of the fortified noodles that were prepared at the same and higher temperatures over the normal preparation temperature. The deep-frying temperatures at 170°C and 175°C did not affect general appearance and acceptability of the deep-fried noodles regardless of fortification. Colour of the fortified noodles that was fried at 175°C was rated to be more appropriate ($p \leq 0.05$). In the case of the dried type, subjects also preferred the products from the higher temperature, with the fortified product being even more acceptable than the unfortified one.

Problem of temperature fluctuation during industrial food production is a normal occurrence in the dehydration processes of both the instant noodles (Fu, 2008). After lysine fortification, the instant noodle products of both types became more sensitive to temperature fluctuation. Lysine is an amino acid that is known to be one of the most sensitive to non-enzymatic browning reaction, Maillard reaction (Caballero, Truso & Finglas, 2003; Meade, Reid & Gerrrard, 2005). Maillard reaction

Table 3. Scores of 'difference from control' (DFC) of colours and acceptability tests of lysine-fortified (F) noodle blocks which had been deep-fried and dried at different temperatures compared to the unfortified (UF) noodles.[1,2]

Type	*Temp (°C)*	*DFC Score*[3]	*Acceptability test* *General appearance*[4]	*Colour suitability*[5]
Deep-fried	UF: 170	5.17 (1.01) [b]	7.17 (1.01) [a,b]	2.54 (0.51) [a]
	F: 165	3.91 (1.56) [a]	6.58 (1.18) [a]	2.04 (0.62) [b]
	F: 170	6.22 (1.00) [c]	7.46 (1.06) [b]	2.79 (0.51) [a]
	F: 175	8.30 (0.70) [d]	7.58 (1.10) [b]	3.29 (0.46) [c]
Dried type	UF: 95	5.27 (1.28) [a]	6.74 (1.36) [a]	2.30 (0.63) [a]
	F: 80	4.77 (0.92) [a]	6.52 (1.41) [a]	2.17 (0.49**)** [a]
	F: 95	5.14 (1.17) [a]	6.70 (1.29) [a]	2.22 (0.52) [a]
	F: 105	7.77 (0.87) [b]	7.04 (0.93) [a]	2.97 (0.37) [b]

[1] Mean (SD) (n = 24).

[2] Means with the same superscript within the same column of the same type of noodles are not significantly different (p>0.05).

[3] Score ranges from 1 = extremely lighter than reference, 5 = no difference from reference, 9 = extremely darker than reference.

[4] Nine-point hedonic scale (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely).

[5] Five-point just-about-right scale (5 = much too dark, 3 = just-about-right, 1 = much too light).

can affect colour change which is unacceptable to the industry. In the present study, the wide range of temperatures used is normal in the production of noodles. The lysine-fortified products had significantly darker colour than the unfortified ones when they were produced under conditions approaching the higher end processing temperatures. However, the colours were still within the acceptable range.

Shelf-life study

Fat content determines the shelf-life of commercial instant noodles. Therefore, the shelf-life study design in the present study took into account that a product of higher fat content normally has shorter shelf life. The dried type instant noodles (1.84 % fat) has a shelf life up to 1 year, therefore the study design planned for a shelf stability test under an 'acceleration condition' at 4 months. For deep-fried type (17.12 % fat) that has a shelf life of 5 months, the shelf stability test was planned for only 2 months. Since the fortified products used for the shelf life study needed to be produced from a large batch at the pilot scale of the instant noodle industry, the degree of lysine homogeneity was therefore evaluated. Percent coefficient of variation of lysine was 5.2 and 1.0 for deep-fried and dried noodle blocks, respectively, which indicated good homogeneity. This finding indicated the feasibility of lysine fortification in normal instant noodle production lines of both types of processed noodles.

Lysine content

During storage under 'acceleration condition', no significant losses of the fortified lysine were found in both types of noodles (Per serving, deep fried: 284.73±13.27 mg at 0th month vs 271.39±7.53 mg at 2nd month; dried: 291.67±5.22 mg at 0th month vs 298.11±4.47 mg at 4th month).

Table 4. Changes in colour of unfortified (UF) and fortified (F) deep-fried and dried noodle blocks during storages.[1,2,3]

Colour value	*Deep fried*			*Dried*		
	Month	*UF*	*F*	*Month*	*UF*	*F*
L*	**0**	77.54(1.21)^{a}	76.28(0.22)^{a}	**0**	85.86(0.71)^{a*}	83.12(0.45)^{b*}
	1	80.02(0.10)^{b*}	78.04(0.32)^{b*}	**2**	85.61(0.46)^{a*}	81.19(0.25)^{a*}
	2	80.45(0.41)^{b*}	79.03(0.03)^{c*}	**4**	85.59(0.18)^{a*}	80.96(0.25)^{a*}
a*	**0**	2.84(0.28)^{b*}	3.58(0.04)^{b*}	**0**	1.54(0.03)^{b*}	0.60(0.04)^{a*}
	1	2.09(0.11)^{a*}	2.65(0.17)^{a*}	**2**	0.49(0.16)^{a*}	4.15(0.08)^{b*}
	2	1.98(0.07)^{a*}	2.47(0.05)^{a*}	**4**	0.33(0.12)^{a*}	4.16(0.13)^{b*}
b*	**0**	27.48(0.19)^{c*}	31.42(0.73)^{a*}	**0**	21.68(0.57)^{a*}	23.30(0.40)^{a*}
	1	25.81(0.07)^{b*}	30.27(0.57)^{a*}	**2**	22.54(0.96)^{a*}	28.94(0.58)^{b*}
	2	25.75(0.32)^{a*}	30.36(0.27)^{a*}	**4**	21.52(0.28)^{a*}	27.45(0.83)^{b*}

[1]Mean (SD) (n = 3)
[2]Means with the same superscript of the same colour value within the same column of the same type of noodles are not significantly different (p>0.05)
[3]Means without asterisk of the same colour value and time within the same row of the same type of noodles are not significantly different (p>0.05)

Colour change

Effect of storage on colour change was observed. Table 4 shows that the L* value (lightness) of both unfortified and fortified deep-fried instant noodles increased during storage. After 1 month, the unfortified noodles had less redness and yellowness colour tones while colour tones of the deep-fried fortified noodles remained unchanged during storage (p>0.05). The lightness values of the dried instant noodles, both unfortified and fortified, were not significantly different. The redness intensity of the unfortified dried noodles significantly decreased while the yellowness intensity remained unchanged. Upon storage, the fortified dried noodles had more redness and yellowness intensities. Due to the production process, the deep-fried noodles originally contained less water activity (0.20 VS 0.65) than the dried ones **(**unpublished data**)**, which could affect the rate of colour changes especially in the lysine-fortified dried noodles. Maillard reaction may be increased not only at high temperature but also at higher water activity until reaching a maximum at water activity of 0.6 - 0.8 (Meade *et al.*, 2005; Fellow, 2000), which means that fortified dried noodles are more sensitive to browning reaction than the deep-fried ones.

Sensory quality

The sensory study also indicated that colour of the lysine-fortified noodles became darker than the unfortified noodles during storage (Table 5). During the storage period of 1 - 2 months, the colour of the lysine-fortified dried noodles turned into an unacceptable orange colour, which in fact did not have much effect on product acceptability after being cooked. However, the fortified dried noodles will not be accepted by the consumer and industry since the general appearance, that is, colour would be quite different from the normal one. Therefore, lysine fortification of dried instant noodle product should not yet be implemented if no further studies are carried out on

Table 5. Sensory qualities of unfortified (UF) and fortified (F) noodle blocks (uncooked) and cooked noodles during storage[1,2,3]

Month	*Noodle block (uncooked)*				*Cooked noodles*					
	General appearance[4]		*Colour suitability*[5]		*Overall acceptability*[4]		*Colour suitability*[5]		*Flavour acceptability*[4]	
	UF	*F*	*UF*	*F*	*UF*	*F*	*UF*	*F*	*UF*	*F*
Deep-fried type										
0	6.92 (1.16) ^{a*}	6.51 (1.40) ^{a*}	2.74 (0.56) ^{a*}	3.70 (0.61) ^{b*}	6.94 (1.10) ^{a}	7.04 (1.05) ^{a}	2.86 (0.40) ^{a*}	3.10 (0.45) ^{a*}	6.78 (1.36) ^{a}	6.96 (1.14) ^{a}
1	7.12 (1.00) ^{a}	7.16 (1.12) ^{b}	2.69 (0.61) ^{a*}	3.37 (0.63) ^{a*}	6.90 (1.46) ^{a}	7.25 (1.15) ^{a}	2.94 (0.31) ^{a}	3.06 (0.37) ^{a}	6.77 (1.49) ^{a}	7.21 (1.09) ^{a}
2	7.18 (0.92) ^{a}	7.02 (1.12) ^{a,b}	2.66 (0.48) ^{a*}	3.48 (0.54) ^{a,b*}	6.72 (1.34) ^{a*}	7.30 (1.04) ^{a*}	2.90 (0.36) ^{a*}	3.04 (0.28) ^{a*}	6.90 (1.25) ^{a*}	7.36 (1.01) ^{a*}
Dried type										
0	6.11 (1.46) ^{a}	5.96 (1.79) ^{b}	2.40 (0.60) ^{a*}	2.98 (0.69) ^{a*}	6.63 (1.61) ^{a}	6.49 (1.76) ^{a}	2.55 (0.54) ^{a}	2.51 (0.54) ^{a}	6.51 (1.74) ^{a}	6.33 (1.79) ^{a}
2	6.22 (1.87) ^{a*}	4.24 (2.00) ^{a*}	2.94 (0.68) ^{b*}	4.46 (0.65) ^{b*}	6.74 (1.60) ^{a}	6.76 (1.65) ^{a}	2.72 (0.50) ^{a*}	3.33 (0.52) ^{b*}	7.00 (1.43) ^{a}	6.76 (1.72) ^{a}

[1]Mean (SD) (n = 50)
[2]Means with the superscript of the same alphabet within the same column of the same type of noodles are not significantly different (p>0.05).
[3]Means without asterisk of UF and F of the same duration of the same sensory characteristics are not significantly different (p>0.05).
[4]Nine-point hedonic scale (9 = like extremely, 5 = neither like nor dislike, 1 = dislike extremely).
[5]Five-point just-about-right scale (5 = much too dark, 3 = just-about-right, 1 = much too light).

Table 6. Amino acid score and profile per requirement for adult 60 kg BW (%) in one serving of deep-fried and dried instant noodles with (w S) and without seasoning (w/o S)

Amino acid	*Deep-fried*				*Dried*			
	Amino acid score (%)		*% Requirement*		*Amino acid score (%)*		*% Requirement*	
	w/o S	*w S*	*w/o S*	*w S*	*w/o S*	*w S*	*w/o S*	*w S*
Ileu	104.3	104.3	80.0	81.2	104.3	104.3	90.0	91.2
Leu	87.1	87.1	112.5	114.5	87.1	87.1	123.2	125.2
Lys	102.2	103.4	148.9	150.7	122.1	123.5	159.6	161.4
Met + Cys	84.3	84.3	44.4	45.5	84.3	84.3	49.2	50.3
Phe + Tyr	94.1	94.1	116.1	121.0	94.1	94.1	112.5	117.5
Thr	72.5	72.5	96.4	99.1	72.5	72.5	92.9	95.5
Tryp	58.9	58.9	50.7	52.3	58.9	58.9	55.7	57.3
Val	96.5	96.5	92.5	94.2	96.5	96.5	97.5	99.2

modification of the present drying condition. The darker colour in fortified deep-fried noodles did not worsen the sensory acceptability of both uncooked and cooked products. The scores for overall acceptability, colour and flavour of the fortified noodles were even better than the unfortified noodles(Table 5).

Amino acid profiles of the lysine-fortified instant noodles

Tables 2 and 6 indicate that lysine fortification could improve protein quality (amino acid scores) of instant noodles. However, not all amino acids in both types of instant noodles were adequate for the serving requirements of an adult of 60 kg body weight (BW) / i.e. methionine, cystine, and tryptophan. Compared to the unfortified noodles, overall nutritive values of the fortified noodles were not different, except for a small increase in protein content (unpublished data). Therefore, the difference in protein quality of the lysine-fortified product may not be an advantage for the food business since the Thai FDA or TISI standards are based only on crude protein content not the protein quality. However, an improvement in protein quality should very much benefit the consumers, especially when instant noodle are the only source of protein for a meal (Hussain *et al.*, 2004; Zhao *et al.*, 2004). After fortification and at the end of the storage period, the residual lysine in deep-fried and dried noodle blocks could contribute up to 102% and 122 % of the amino acid score of lysine, respectively**.** In order to obtain actual protein quality, *in vitro* protein digestibility must be evaluated and used as the factor for multiplication with the amino acid score (Protein Digestibility Corrected Amino Acid Score (PDCAAS)), which normally might result in slightly lower values of the original amino scores (Schaafsma, 2000). Based on the US Food and Nutrition Board (2005) which recommends higher amino acid intakes per kg BW per day, the percent adequacies of amino acids from lysine-fortified instant noodles might be lower (Food and Nutrition Board, 2005).

Cost of lysine fortification

The cost of lysine for fortification in noodles was about 0.09 baht (0.27 US cents) / package of 55 g. This value should be the net of fortification cost since additional equipment is not needed. Based on the current price of instant noodles, the cost of fortification is only 1.7 % of the product price, which is still within an acceptable range (Allen *et al.*, 2006).

CONCLUSION

It is feasible to improve protein quality of deep-fried instant noodles to 102 % amino acid score of lysine by fortifying L-lysine monohydrochloride in noodle blocks at 0.23 g / 1 serving of 50 g. The cost of fortification is 1.7 % of the sale price. Fortification of lysine in dried type instant noodles resulted in an unacceptable colour during storage. No additional process is required for the food industry.

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REFERENCES

Allen L, Benoist B, Dary O & Hurrell R (2006). Guidelines on Food Fortification with Micronutrients. World Health Organization, Geneva.

Anjum FM, Ahmad I & Butt MS (2005). Amino acid composition of spring wheats and losses of lysine during chapati baking. *J Food Comp Anal* 18: 523-532.

Caballero B, Truso LC & Finglas PM (2003). Encyclopedia of Food Science and Nutrition. Volume 1(2nd ed.). Academic, San Diego, California.

Fellows P (2000). Food Processing Technology. Principles and Practice. CRC Press, Boca Raton, Florida.

Flodin N W (1997). The metabolic roles, pharmacology, and toxicology of lysine. *J Am Coll Nutr* 16(1): 7-21.

Food and Agriculture Organization of the United Nations & World Health Organization, FAO / WHO (1991). Protein Quality Evaluation. Report of the Joint FAO / WHO Expert Consultation. Bethesda, Maryland.

Food and Nutrition Board (2005). Dietary Reference Intakes: For Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein and Amino Acids. National Academy Press, Washington, DC.

Fu BX (2008). Asian noodles: history, classification, raw materials, and processing. Food Research International. *Cereal Foods* 41: 888-902.

Hong JL, Bi YC, Hui WY, Feng HU & Xing XL (1995). Detemination of amino acid in food and feed by derivatization with 6-Aminoquinoyl-*N*-Nydroxy-succinimidyl carbamate and reverse-phase liquid chromatography separation. *J Assoc Off Anal Chem* 78: 736-744.

Hussain T, Abbas S, Khan MA & Scrimshaw NS (2004). Lysine fortification of wheat flour improves selected indices of the nutritional status of predominantly cereal-eating families in Pakistan. *Food Nutr Bull* 25: 114-122.

Kounhawej A (2005). Effect of different iron fortificants on qualities and in vitro iron bioavailability of instant noodles. Master Thesis of Science [Food and Nutrition for Development], Faculty of Graduated Studies, Mahidol University, Nakhonpathom, Thailand.

Meade SJ, Reid EA & Gerrard JA (2005). The impact of processing on the nutritional quality of foods proteins. *J Assoc Off Anal Chem* 88(3): 904-922.

Ministry of Public Health (1990). Amino Acid Content of Thai Foods. Nutrition Division. Department of Health. Ministry of Public Health. Bangkok.

MOST (2005). The USAID Micronutrient Program, Roche Pharmaceuticals. Fortification Basics, Instant Noodles: A potential vehicle for micronutrient fortification.Online *http://www.mostproates_Feb05/noodles.pdf* [Accessed 2008 February].

Peace RW & Gilani GS (2005). Chromatographic determination of amino acids in foods. *J Assoc Off Anal Chem* 88(3): 877-887.

Sabine L & Brian SE (2004). A Handbook of Statistical Analyses Using SPSS. CRC Press, Boca Raton, Florida.

Schaafsma G (2000). The protein-digestibility corrected amino acid score. *J Nutr* 130: 1865-1867.

Sun SW, Lin YC & Weng YM (2006). Efficiency improvements on ninhydrin method for amino acid quantification. *J Food Comp Anal* 19: 112-117.

Taeteang W (1996). Improvement of nutritive values of instant noodles. Master Thesis of Science [Food and Nutrition for Development], Faculty of Graduate Studies, Mahidol University, Nakhonpathom, Thailand.

Tongpun N (2006). Formulation of soy protein-enriched instant noodles. Master Thesis of Science [Nutrition], Faculty of Graduate Studies, Mahidol University, Bangkok, Thailand.

World Instant Noodles Association (2008). Instant Ramen Facts-Worldwide. Online *http://www.instantramen.or.jp/english/data/data02.html* [Accessed 2008 February].

Yoshida A (1990). Nutrition: Proteins and Amino acids. Japan Scientific Societies Press, Tokyo.

Zhao W, Zhai F, Zhang D, An Y, Liu Y, He Y, Ge K & Scrimshaw NS (2004). Lysine-fortified wheat flour improves the nutritional and immunological status of wheat-eating families in northern China. *Food Nutr Bull* 25: 123-129.