DEVELOPMENT OF A METHOD FOR HEAT-TREATMENT RESISTANCE EVALUATION OF RICE NOODLES

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Sales and market share for rice noodles and other rice-based products in the export market (i.e. Europe) have markedly increased over the past few years. Scientific Organizations around the world do not have any method for determining the heat stability of rice noodles subjected to pasteurization/sterilization conditions. This study aimed to develop a method for evaluating the heat-treatment resistance of a rice noodle and to establish a simple test capable of differentiating the stability of a rice noodle at pasteurisation/sterilisation conditions. It also aimed to conduct a parametric study dealing with the development of rice noodles resistant to heat treatment.

In developing the method, seven parametric tests basically used to measure quality of noodles/pasta were screened. Five rice noodle samples were used. Pasteurisation test was employed on the samples and its result was correlated with the data obtained from the seven parametric tests. Of all the parametric tests, Total Cooking Loss (TCL) was found to be the simplest and most practical test capable of giving very strong correlation (r=0.91). Validation for TCL test was performed. Stable and a non-stable samples were used. Three simple methods of heat-treating noodles (i.e. small bag, closed beaker, open beaker) were chosen to be performed. It was found that the open beaker method was the simplest method capable of representing the condition used in the industry and was thus validated. The open beaker method, being TCL and visual inspection as the main parameters, was refined and was then referred to as the “Stability Test”.

To further determine the capability of the developed method, a parametric study on the development of heat resistant rice noodles was simultaneously performed. European and Asian rice varieties and one commercial rice flour with varying amylose levels were used. Monoglyceride (DIMODAN PH 200) and high amylose starch (CRISP FILM) were used to promote complexation and retrogradation, respectively. Treatments on each variety were designated as follows: control (To), complexation-treated without additive (T1), complexation-treated with additive (T2), retrogradation-treated without additive (T3), and retrogradation-treated with additive (T4). The Asian rice variety having the highest amylose content was found to give the most stable samples. Decreasing the amylose content also decreased the stability of the samples. “Retrogradation-intended processes (RIP)” were found to be more beneficial and influential on noodle stability than those “Complexation-intended processes (CIP)”. RIP gave the noodles of more acceptable visual aspect and greater stability whereas CIP were found to reduce stickiness on noodles but did not contribute much on the stability of the samples. Statistical analysis indicated that stability does not solely depend on the variety or process but also on the combined effect of these two factors. Thus, in producing heat-resistant rice noodles, the right variety (having intermediate to high amylose content) and the right process (intended to promote retrogradation) should be carefully chosen so that a stable structure could be formed. The result also implies that methods measuring physico-chemical properties of rice (i.e. amylose content, etc.) are not really enough to predict stability of rice noodles since it is not solely the variety that affect stability, but also more importantly the process. The results further strengthened the capability of the developed method in evaluating the heat-treatment resistance of rice noodles.

1. INTRODUCTION

There has been steady European demand for cereals and cereals-based products for human consumption but rice is an exemption (Faure and Mazaud, 1995). The market share for rice is increasing and expanding in many countries especially those in the European Community *(Yap, 2003)*. In addition to such trend, tropical products are now getting a good market in Europe. People are now becoming so keen in trying new products and in diversifying their conventional diets. As such, tropical foods like rice has become of great interest for European manufacturers seeking new food products. Actually, the processed rice industry is now also focusing on rice-based convenience foods.

The development of such products, as what the manufacturers believed, is a brilliant way to segment the rice market and at the same time, provide better margin for them. As a matter of fact, several frozen or pasteurized cooked rice dishes and rice products have been launched by the manufacturers and large grocery stores. Although this still account for a small share of the rice market, it was recently observed that sales of these products have markedly increased over the past few years *(Faure and Mazaud, 1995)* and therefore may further give promising trend in the future. Among the rice-based products which has also gained interest in the European market is the so-called ''rice noodle''.

Rice noodles are traditional food for the Asians and are said to be the most popular form of rice products in South East Asia. Although good quality noodle is usually obtained from durum wheat, the production of noodles from rice is now achieving a great marketing importance especially in the European countries. This is because the production of rice noodles complement the increase in rice consumption and changing food habits which are said to be a part of a general dietary diversification trend that is currently happening in Europe *(Faure and Mazaud, 1995)*. According to *Yap (2003)*, the expansion in demand in these countries stems from a variety of factors. They include the increasing willingness of people to try new foods, the conscientious attempts of some to cut down the consumption of meat products and to consume greater quantities of alternative ''healthier less meat-based diets'' and the existence of different ethnic groups with their prevailing rice diets.

The technology of rice flour as a raw material for rice noodle production has already resulted to good quality products (e.g. vermicelli, kanom jeen, flat noodle, etc.) This is especially true in the case of rice noodles which are intended for domestic use. The problem arises when such rice noodles are offered for industrial use in the export market which aim is to produce a cooked pasteurised/sterilised product able to be stored at ambient temperature. Pasteurisation and sterilisation treatments are now successfully being applied on durum wheat-based noodles and on some starch noodles (i.e. mungbean) but still not so successful on rice-based noodles. It was found that some rice noodles tended to become mushy after heat treatment is applied. At present, there is no established and published method and test that can measure the stability of noodles subjected to heat treatments (i.e. pasteurisation, sterilisation).

In Asia, rice noodle manufacturers and exporters have no way of determining whether the noodle they produce would be stable to heat-treatments applied in the export industries (i.e. Europe). Products are sometimes rejected and sent back to the rice noodle exporter if the noodles were found to be not heat-stable. Manufacturers do not have know-how on how to possibly produce stable rice noodles. As a result, this incurs huge economic/monetary losses to the exporter.

Mestres et al*. (1988)* made a study on the characteristics of starch networks found in rice and mungbean noodles. They found that such gluten-free noodle products contain amylose- based crystallites which were highly resistant to mild acid hydrolysis and melted at high temperatures (above 100°C). These crystallites were found to be either in the complexed form (V-type) or in the retrograded form (B-type). Pasteurisation and sterilisation temperatures applied on rice noodles by the European Industries range from 98-121°C. It is by these reasons why these amylose-based structures should be given emphasis in an attempt to produce a stable rice noodle and at the same time in developing a method. The method should be able to directly reflect the imperfections in the noodle structure.

With such current problem, it is very clear that there is a need to develop a method for evaluating the heat treatment resistance of rice noodle at pasteurisation and sterilisation conditions. The method that would be developed may provide Asian rice noodle manufacturers/exporters enough capacity to screen the rice noodle products that they intend to export in Europe. This may prevent the Asian rice noodle manufacturers and exporters from suffering huge monetary losses to their business. Along with the development of the method, a parametric study on the development of heat stable noodles should be conducted in order to further understand what mainly influence the product's stability. The processes/technologies and the raw materials (e.g. rice varieties, additives) may possibly provide information about their role in defining the rice noodle quality characteristics that will be examined. This may also help the rice noodle manufacturers in producing the right stable product. As a whole, this study would then answer the needs of the Food Industries whose main goal is to enter the export market. More importantly, the study would give techniques and additional knowledge to the Scientific communities in evaluating rice noodles resistant to heat treatment.

Objectives of the study

The aim of this study was to be able to develop a method for heat treatment (i.e. pasteurisation, sterilisation) resistance evaluation for rice noodle which can be practically performed in a small laboratory. Furthermore, it aimed to establish a simple test capable of evaluating and differentiating the stability of a rice noodle at pasteurisation/sterilisation conditions. Moreover, it aimed to conduct a parametric study about the stability of flat rice noodles.

The specific objectives of this study were;

1. To screen some quality measurement tests and methods which could possibly reflect the stability of a sample;
2. To try some raw material, additives, processes, and conditions which can possibly give rice noodle able to withstand pasteurisation/sterilisation conditions;
3. To perform characterization of rice noodles in terms of visual, cooking, textural (stickiness), microscopic and thermal properties; and
4. To suggest a noodle technology that might give a stable flat rice noodle using available knowledge, bibliography review, varieties and additives.

Time and place of the study

This study was conducted from March to December 2003 at CIRAD, Montpellier, France under the supervision of Mr. Olivier Gibert and Dr. Jean-Michel Meot in close coordination with ERIDAN partners in Lyon, France.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Rice varieties

Three european rice varieties, one asian rice variety, and one commercial rice flour with varying amylose levels were used to produce rice noodles in conducting the parametric study. The European rice varieties, namely Thaibonnet, Fidji, and Arelate were selected and provided by Semences de Provence (Sud Céréales), Arles, France while the Asian variety, namely Suphanburi I, was procured by ERIDAN Ltd. (Thailand). Furthermore, commercial heat-treated rice flour R7-200 T was provided by REMY Industries, Belgium.

2.1.2 Rice noodles

Five rice noodle samples differing in characteristics and processing methods were used in the screening of the basic parametric tests. These were RFT2, EFN, ERV, SB, and ZN. RFT2 is a flat rice noodle done in CIRAD without any process improvement Both EFN and ERV were supplied by ERIDAN Ltd. (France) while SB and ZN were purchased in a Chinese supermarket in Lyon, France.

2.1.3 Additives

Two additives namely, DIMODAN PH 200 (E 471) and CRISP FILM (E 1420) were used. The former was provided by DANISCO and is a distilled monoglyceride expected to promote complexation. The latter, on the other hand, was provided by National Starch and Chemical Company and is a high amylose starch expected to promote retrogradation. DIMODAN PH 100 and CRISP FILM were employed at 1% and 5% level, respectively, based on the weight of the rice flour used.

2.2 Methods

2.2.1 Development of the method

Figure 1 shows the process flow in developing the method.

2.2.1.1Screening and validation of the test

Simple quality measurements tests (QMT), basically used to measure quality of pasta/noodles, were conducted on some rice noodles. Data were correlated with the results on the visual aspect after pasteurisation in order to know if such tests can be used to predict the quality of rice noodles that can resist heat-treatment. QMT include Optimum cooking time (OCT, *Matsuo and Irvine, 1970)*), water absorption index (WAI, *Khandker* et al*. 1984*), Cooking Loss-Conventional Method (CL-CM, *Debbouz* et al*. 1995*), Cooking Loss-Lodnitap Procedure (CL-LP, *David 1997*), Total Cooking Loss (TCL, *Mestres* et al., 1988), Soluble Loss (SL, *Mestres* et al., 1988) and Insoluble Loss (ISL, *Mestres* et al., 1988). Visual aspect of each sample (after pasteurisation) was evaluated using a numeric camera by assigning a numerical value being 1 as not stable, 2 as partially stable and 3 as stable.

2.2.1.2 Screening and validation of the method

In validating the results obtained from the QMT, stable and non-stable rice noodle samples were used. These were ERIDAN flat noodles and RFT2 samples, respectively. Four methods were compared at sterilisation (1hr ; 121°C) and pasteurisation (100°C) conditions. These methods include Large bag, small bag, open beaker, and closed beaker. Large bag represents the condition performed in the industry whereas small bag, open beaker, and close beaker are simple methodologies which are expected to represent the condition in Large Bag. Parameters used to compare each method include total cooking loss and visual aspect of the samples. The method was further refined and characterized through statistical techniques (*AACC, 1983)*.

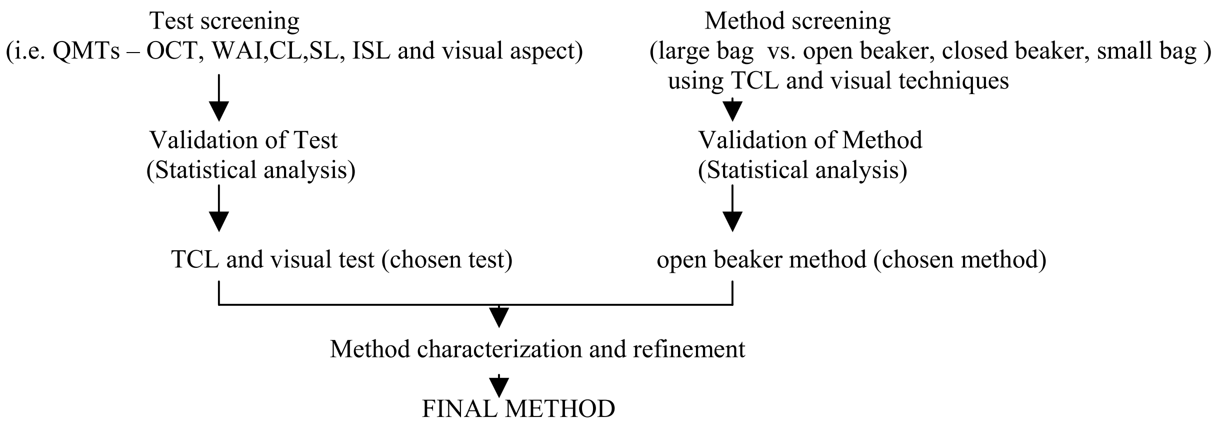


Figure 1. Flow diagram in the development of method.

2.2.2 Parametric study on rice noodles

Figure 2 shows the flow diagram in the conduct of parametric study on rice noodles.

2.2.2.1 Thermal properties of rice noodles

DSC analysis was used to determine the amylose-lipid complex endotherm using the method used by *Mestres* et al*. (1988)* with some modifications. Transition enthalpy (ΔH) as well as the melting/transition temperatures were evaluated using the Perkin Elmer Pyris Instrument Analysis Software.

2.2.2.2 Microscopic property of rice noodles

Microscopic property of the noodles to determine the presence or absence of retrograded amylose was performed using the method described by *Mestres* et al*. (1988)*. The presence of birefringent structures indicated the presence of retrograded amylose.

2.2.2.3 Texture (stickiness)

Stickiness of samples was performed using a refined adhesive test obtained from Stable Microsystems (ref. *PTA4/PFS* revised in 2000) using a TA-XT2 instrument. The test consists of an adhesive textural test on a Ta-XT2 texturometer using its specific adhesion cell HDP/PFS. The force to separate the probe from the sample surface was recorded and given as a measure of stickiness.

2.2.2.4 Visual aspect

In the parametric study on rice noodles, visual evaluation using a numeric camera was re-scaled in order to effectively screen the quality and stability of a sample that had been shown resistant or partially stable. Original scale of 1 to 3 was changed to 0 to 4. The mark “0” represents a perfectly stable sample, 1 as mostly stable structure, 2 as partially stable, 3 as mostly unstable structure and 4 as completely melted structure.

2.2.2.5 Stability (TCL after sterilization)

Stability test performed at sterilisation condition (2 bar pressure; 1 hour) was performed by evaluating the visual aspect of the sample using a numeric camera and then followed by performing a modified TCL procedure. Samples were cooked for 2 minutes, drained for 1 minute, and put in a metallic beaker. Salt solution (1% w/w) was added at a 60:40 cooked rice noodle to salt solution ratio. Oil (11.5% of the total weight of cooked noodle) was also added. The mixture was well-mixed and put in a pressure cooker. Sterilisation was performed at 2 bars pressure (corresponding to 121°C) for 1 hour.

Stability test was completely performed by immediately removing melted parts of the noodles after sterilisation prior to washing. This method was based on washing the sample to quantify the amount of materials lost and/or particles that leached out from the noodle strands. At least 100 ml distilled water at room temperature was used to soak 10 g of sample for 4 minutes. After 4 minutes soaking, the sample was stirred for 15 times and was then drained. Soaking and washing was performed 3 times. In between washing, samples sticking to each other were separated by hand in order to allow maximum exposure of the noodle’s surface to washing water. Washed samples were then dried in a laboratory oven set at 105°C for at least 48 hours or until constant weight.

Identification of Varieties and process

↓

Trials

↓

Treatment desination (Factor A = ariety; Factor = Process)

↓

Noodle characterisation (usin the developed method)

↓

Conclusion

↓

KNOWLEDE READY FOR TRANSFER

Figure 2. Flow diagram in the conduct of parametric study.

2.2.2.6 Treatment designation for each variety

Three European rice varieties (i.e. Arelate, Fidji, Thaibonnet), one Asian variety (Suphanuri I), and one commercial rice flour (R7 200 T) were the rice materials used in combinations with the five processes/technologies to produce the necessary 25-treatment combinations as shown below:

2.2.2.6.1 Control

The control (T0) was prepared by weighing about 500 grams of rice flour and a certain amount of tap water to produce a mixture having a moisture content of about 40% (wet basis). From the weighed flour, a portion is taken to produce a gelatinised slurry with a composition of 1:10 rice flour to water mixture. The slurry was gelatinised to act as a binder by placing in a boiling water bath. The gelatinised slurry was then mixed with the rest of the flour. The mixture was then fed into the press (*Pastellines*) to produce shaped samples. The shaped samples were dried using 2 drying steps: 2 hours at 75°C with a relative humidity of 50-75% followed by drying at a temperature of 60°C, 35% RH for at least 12 hours. Samples were then vacuum packed and kept at room temperature until use.

2.2.2.6.2 Complexation-treated sample without additive

The complexation-treated samples without additive (T1) were prepared with reference to the control. The only difference is that prior to drying, the shaped samples were sprayed with tap water to allow more water to gelatinise the starch and were then steamed for 1 hour at 100°C. The steamed samples were allowed to rest for 15 minutes (not removing the cover of the pilot plant steamer), rest again for 15 minutes by packing in plastic bags, re-steamed for another 15 minutes, washed or re-sprayed again with tap water to separate the noodles and then finally dried using the two-step drying applied on the control. Samples were then vacuum packed and kept at room temperature until use.

2.2.2.6.3 Complexation-treated sample with additive

The complexation-treated samples with additive (T2) were prepared with reference to the previous treatment (T1). The only difference is that the additive (DIMODAN PH 200) was dispersed in the required amount of water (60-70°C) with continuous stirring for 15 minutes. From the weighed flour, a portion is taken to produce a gelatinised slurry with a composition of 1:10 rice flour to water mixture. The small portion of flour was then mixed with the dispersion and the mixture was then put in a boiling water bath to gelatinise the flour. Samples were then processed using the procedure used on the previous treatment. After drying, samples were then vacuum packed and kept at room temperature until use.

2.2.2.6.4 Retrogradation-treated sample without additive

The retrogradation-treated samples without additive (T3) were prepared with reference to the control. The only difference is that prior to drying, the shaped samples were sprayed with tap water and were then steamed for 1 hour at 100°C. The steamed samples were allowed to rest for 15 minutes (not removing the cover of the pilot plant steamer), rest again for 15 minutes by packing in plastic bags, re-steamed for another 15 minutes, kept at 4°C for 2 hours, allowed to rest at room temperature overnight, and then finally dried using the two-step drying applied on the control. Samples were then vacuum packed and kept at room temperature until use).

2.2.2.6.5 Retrogradation-treated sample with additive

The retrogradation-treated samples with additive (T4) were prepared with reference to the previous treatment (T3). The only difference is that the additive used (CRISP FILM), was dispersed in the rice flour. Samples were processed using the procedure used on the previous treatment and the dried samples were then vacuum packed and kept at room temperature until use.

2.2.2.7 Statistical analysis and experimental design

2.2.2.7.1 Development of the method

Simple correlation analysis was performed to determine any possible direct relationship of some simple cooking tests (i.e. OCT, WAI, CL-CM, CL-LP, TCL, SL, ISL) with that of the Pasteurisation Test. All determinations were done in triplicates.

Analysis of Variance in Completely Randomized Design was used in the interpretation of the results when comparing the four methods of heat treatment at pasteurisation condition whereas t-test was used when comparing two methods of heat treatment at sterilisation condition. All determinations were done in duplicates.

Refined Total cooking loss (TCL) data of stable and unstable rice noodles at sterilisation condition were subjected to Analysis of Variance to get the Mean Square Error. The estimated variance of the treatment mean was then calculated *(AACC, 1983)* to get the Relative Efficiency of the Refined TCL test when testing stable and unstable samples.

2.2.2.7.2 Parametric study on rice noodles

Factorial in Completely Randomized Design (Crossed Model) was used in the interpretation of the results in Visual Observation, Total Cooking Loss and Texture Evaluation. Results of the test were subjected to multi-Factor Analysis of Variance. Where significant differences were observed, comparison among means was determined using Newman-Keul's multiple Range Test at 5% significance level. In determining the factor which gave the most significant influence on the noodles, multi-variate ANOVA statistics were performed. All determinations were done in duplicates. All statistical analysis were performed using the procedure of Statgraphics Plus 2.1 Software.

3. RESULT AND DISCUSSION

3.1 Development of simple test
3.1.1 Screening of some basic quality measurement tests (QMT)

The results on the cooking and pasteurisation tests done on the five noodle samples in order to know which of the tests can be used to predict the stability of rice noodle is shown below (Table 1).

Table 1. Cooking tests and pasteurisation tests employed on some rice noodles

Sample	Cooking Test							Pasteurisation Test
	OCT (min)	WAI (%)	CL-CM (%)	CL-CP (%)	TCL (%)	SL (%)	ISL (%)	Visual Aspect*
RFT2	3.8	102.7	16.6	9.0	15.0	7.8	5.9	1
EFN	4.3	198.1	5.5	3.9	4.2	2.1	1.8	3
ERV	3.7	205.9	6.9	4.2	6.4	4.0	1.9	3
SB	3.2	238.1	3.1	1.9	1.8	0.8	0.9	3
ZN	17.2	161.5	11.5	8.7	7.1	4.7	1.9	3

*1 – not stable; 2 – partially stable; 3 – stable
**pink shade indicates highest value while yellow shade indicates lowest value

The first test, optimum cooking time (OCT), simply reflects on how many minutes will it take for a noodle before it can be cooked. As shown, the ZN rice noodle required the longest cooking time (17.2) while the SB rice vermicelli had the lowest cooking time (3.2).

When it comes on the water absorption index (WAI), SB rice vermicelli absorbed the highest amount of water (238.1) while the RFT2 flat rice noodle got the lowest (102.7). *Bhattacharya* et al.. *(1999)* mentioned that high rehydration after cooking indicates that the noodles has a good cooking tolerance. The result then implies that RFT2 having the lowest WAI would be expected to have the lowest cooking tolerance while SB having the highest WAI would then be expected to have the highest cooking tolerance.

The remaining tests, cooking losses, simply reflect the ability of a rice noodle to resist disintegration in cooking water. These include cooking loss using the conventional method (cl-cm), lodnitap procedure (cl-lp), and total cooking losses (TCL) – which include the soluble loss (SL) and insoluble loss (ISL). As was observed, the three tests consistently produced the same trends. The SB rice vermicelli showed the highest resistance to disintegration on cooking water while the RFT2 sample showed the lowest. *Bhattacharya* et al.. *(1999)* also mentioned that high cooking losses represents low cooking tolerance. The result then implies that SB has the highest cooking tolerance while RFT2 would be expected to have the lowest cooking tolerance.

Cooking loss and degree of swelling are said to be two important factors influencing the cooking quality of noodles (*Bhattacharya* et al.*, 1999*). Although with the exception of few varieties, *Khandker* et al*.* (1986) found that low amylose flours had higher WAI values than high amylose flours. Furthermore, high amylose flours particularly those with higher consistency are said to have greater stability and higher resistance to disintegration on overcooking *(Juliano, 1979 as cited by Khandker, 1984)* and would therefore be expected to have low cooking losses. As such, the results obtained on the noodles above contradict each other. SB rice vermicelli was found to have the highest WAI, which is then expected to have the lowest amylose content, but it was found to have the lowest cooking losses, which should be then expected to have the highest amylose content. Thus, the result clearly indicates that it is not only the amylose content which influences the characteristics of the above noodles.

The result on pasteurisation test reflected the stability of the noodles at pasteurisation condition. As shown, a scale of 1 to 3 was assigned for each observation (1 – not stable; 2 – partially stable; 3 – stable).

As shown on Table 2, correlation coefficients (r) for each test varied from 0.24 to 0.97. Among the tests, it was found that the OCT ($r \approx 0.24$) was found to have a weak linear relationship with the pasteurisation test while the ISL ($r \approx 0.97$) gave the strongest correlation.

Table 2. Value of correlation coefficient for each QMT

Cooking Test	Correlation Coefficient (r)	Interpretation
OCT	0.24 -	weak
WAI	0.85 ***	Very strong; positively correlated
%CL CM	-0.82 ***	Very strong; negatively correlated
%CL LP	-0.62 **	Strong; negatively correlated
%TCL	-0.91 ***	Very strong; negatively correlated
%SL	-0.82 ***	Very strong; negatively correlated
%ISL	-0.97 ***	Very strong; negatively correlated

***,**,**-Strength of linear relationship for r>0.8, 0.8<r<0.6, 0.6<r<0.4, respectively.
*pink shade indicates highest value while yellow shade indicates lowest value

The results obtained from the QMTs were found to be capable of discriminating differences among samples. Also, the tests consistently produced the same trend on each result specifically that on Cooking Losses. When the result from the QMTs and Pasteurisation Test were correlated, the % Insoluble Loss gave the highest value of correlation coefficient (r ≈-0.97). It means that among the tests, the %ISL has the strongest (negative) relationship with the stability of the rice noodles and might therefore be possibly use as a screening test. The correlation suggests that as the cooking loss decrease, the stability of the noodle increase.

In spite of the high value of correlation coefficient of ISL, it was noted that such test also had some short comings. First is that it requires some steps to separate the sediment from the cooking water and therefore consume some time to complete the analysis. Second is that the test require an additional equipment (i.e. centrifuge) to proceed with the analysis of the samples. With this, the TCL test having the next highest correlation was eyed as the simple test which can replace ISL because the former also gave a strong inverse relationship (-0.91) with the Pasteurisation Test. As such, it was decided that the TCL would be the main parameter which will be used to differentiate a stable from a non-stable sample when subjected to pasteurisation or sterilisation conditions.

3.1.2 Validation of the method and test

As shown on Table 3, a stable sample (EFN) was first used to validate the result obtained from the Screening of Quality Measurement Tests at pasteurisation condition. Four methods (i.e. large bag, small bag, open beaker, closed beaker) of pasteurising noodles were used to determine the heat stability of samples. Large bag represents the condition used in the industry while the rest are simple methodologies that are expected to represent the condition in the large bag. The table below also shows the results on moisture content, total cooking losses and visual inspection after heat treatment.

Table 3. Pasteurisation quality test results on stable sample*

Method of Pasteurisation	%MC	%TCL	Visual aspect **
Large bag	65.6	1.9	1
Small bag	65.3	2.2	1
Open beaker	63.6	1.7	1
Closed beaker	61.2	1.1	1

(*) stable sample used is EFN.
(**) 1,2 and 3 respectively as stable, partially stable and unstable.

On visual inspection, ERIDAN flat noodle (EFN) was found to be stable (1) whatever method is used to pasteurise the sample. Moisture content was found to be lowest in open beaker (61.2) while highest in large plastic bag (65.6). Total cooking loss of sample in closed beaker was found to be lowest (1.1) while highest in small bag (2.2).

Statistical analysis showed that on all the parameters measured (i.e. moisture content, total cooking loss), there exists no significant differences whatever method is used to determine quality of samples subjected to pasteurisation conditions. This suggests that all methods give similar results irrespective of the procedure used to perform the pasteurisation test on stable sample (ERIDAN flat noodle). This further means that the 3 simple methods (i.e. small bags, open beakers, closed beakers) are capable of giving similar results when compared to the standard (large bag) which is the condition representing what is performed in the industry.

Since it was found that the 3 simple methods (i.e. small bag, open beaker, closed beaker) gave similar results when compared to the standard (large bag), it was decided that the open beaker would be used to compare with the large bag method in testing an unstable sample (RFT2). It is because Open Beaker was the simplest to be performed among the three methods in a small laboratory.

Table 4 shows results on unstable sample (RFT2 sample) subjected to two methods of pasteurisation (i.e. large bag, open beaker). Total cooking loss was higher in large bag (21.4) as compared in an open beaker (18.0). On visual inspection, sample pasteurised using the 2 methods were found to be partially melted (2).

Table 4. Pasteurisation quality test results on unstable sample*

Pasteurisation conditions	%TCL	Visual aspect **
Open beaker	18.0	2
Large bag	21.4	2

(*) unstable sample used is RFT2.
(**) 1,2 and 3 respectively as stable, partially stable and unstable.

When the result obtained from the non-stable sample (RFT2) was compared with the result obtained from the stable sample (EFN), it was found that there exists a significant difference between the Total Cooking Loss of the two samples. It simply means that the developed Pasteurisation Test being TCL as the main parameter is capable of discriminating a stable from a non-stable sample at pasteurisation condition.

Table 5 shows the result on the stable samples subjected at Sterilisation Condition. The ERIDAN flat noodle was found to be stable (1) whatever method is used to sterilise the sample. Moisture content and TCL were higher in packaging (67.6 and 1.44) than in open beaker (66.0 and 0.9).

Table 5. Sterilisation quality test results on stable sample*

Sterilisation conditions	%MC	%TCL	Visual aspect **
Packaging	67.6	1.4	1
Open beakers	66.0	0.9	1

(*) stable sample used is EFN.
(**) 1,2 and 3 respectively as stable, partially stable and unstable.

Table 6 shows the result of the sterilisation test done on the unstable sample (RFT2). As shown, TCL in packaging was higher (49.5) than in open beaker (19.9). RFT2 was found to be partially melted (2) in both method.

Table 6. Sterilisation quality test results on unstable sample*

Sterilisation conditions	Cooking ratio	%TCL	Visual aspect **
Open beakers	143.4	19.9	2
Packaging	157.6	49.5	2

(*) unstable sample used isRFT2.
(**) 1,2 and 3 respectively as stable, partially stable and unstable.

Statistical analysis also showed that there exists a significant difference between the TCL of the two samples. The result suggests that the method is also capable of discriminating a stable from a non-stable sample at sterilisation condition. Figure 3 shows the ability of the method in discriminating a stable from a non-stable sample.

a b

Figure 3. Photos of (a) stable and (b)non-stable samples used in the study.

3.1.3 Refinement of the method

As discussed above, the open beaker method being TCL and visual inspection as the main parameters was validated as the simplest method which could represent the condition performed in the industry at pasteurisation and sterilisation conditions. Furthermore, such method was also proven to be capable of discriminating a stable from a non-stable sample. The developed method had therefore answered the need of rice noodle manufacturers and exporters in Asia when evaluating the heat stability of their rice noodle samples. The step-by-step component of the developed method is shown below (Figure4):

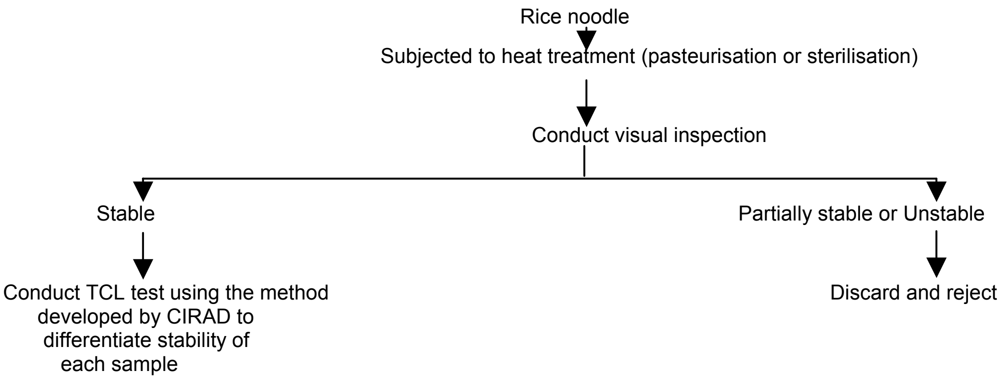
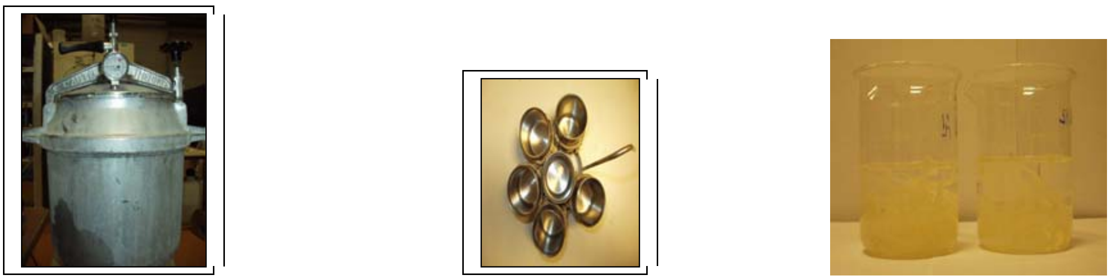


Figure 4. Flow diagram of the developed method (open beaker) in evaluating rice noodle samples.

In the newly-developed Open Beaker Method, when the sample is found to be unstable, it will be discarded. In contrast, when the sample is found to be stable, the sample will be subjected to TCL after heat treatment is applied. However, for the purpose of characterizing the stability of extruded noodles used in the parametric study, it was decided that the method should be refined. The said Open Beaker Method was refined as follows: If the sample is found to be stable, it will be directly subjected to TCL determination but if the sample is unstable, the melted part will be removed and that only the remaining strands will be subjected to TCL determination. The purpose of refining the method is just to visualize the amount of noodle that still remained whole or stable after heat treatment. Figure 5 shows the developed open beaker method with the Total Cooking Loss (TCL) Test.



a b c

Figure 5. The developed open beaker method utilizing a laboratory autoclave (a) with the metallic open beakers (b) and the TCL test.

3.1.4 Characteristics of the developed Total Cooking Loss (TCL) test

The relative efficiency of the developed TCL test when testing stable and unstable samples is shown on Table 7. Relative efficiency of the test is measured in terms of Mean Square Error or simply the variances due to error. MSE measures the magnitude of errors in an experiment *(Statgraphics, 1995)* which somehow measures the precision of an experiment. The MSE, also termed as error variance, denotes for the unexplained variances in an experiment. As shown, the mean square error of the developed TCL when testing stable samples is 0.4 whereas its mean square error when testing unstable samples is 15.5. When the Estimated Variance of the treatment mean was computed, it was found that the TCL when testing the stable samples has a value of 0.1 whereas in the case of unstable samples, it gave a value of 3.9. As known, a design or a model which provides a smaller estimated variance of a treatment mean than does some other design is the more efficient of the two *(AACC, 1983)*. The result therefore suggests that the developed TCL is more precise and more efficient in testing stable samples than when testing unstable samples. Although the efficiency of the TCL decreased when testing unstable samples, this finding will not affect the credibility of the method and test since rice noodle manufacturers and exporters are only interested to quantify the stability of the stable rice noodles and not on the unstable samples because the latter will always be immediately rejected or discarded after heat treatment. Furthermore, the relative efficiency obtained in this study only showed that experimental errors increase when testing unstable samples. This is maybe due to the fact that unstable samples are in general difficult to handle during TCL testing because unstable noodles tended to stick together after heat treatment. In the test, noodles sticking to each other should be as much as possible be removed in order to expose the noodle's surface to the washing water. This is one of the possible sources of error of the test.

Table 7. Relative efficiency of the developed TCL test when testing stable and unstable samples

Stability of Samples	Mean Square Error (MSE)	No. of samples used (n)	Estimated variance of a treatment mean (MSE/n)
Stable	0.4	4	0.1*
Unstable	15..5	4	3.9

*denotes more efficiency.

3.2 Parametric study on the stability of rice noodles

As shown on Table 8, moisture content of rice flours used to produce noodle varied from 9.3% to 10.6%. Rice flours used were found to have low to intermediate amylose content. Low amylose content was found for Arelate (16.5%) while intermediate amylose contents which were 20.6%, 20.8%, 23.5%, and 23.7% were found for Remy, Fidji, Thaibonnet, and Suphanburi I, respectively. Thaibonnet was expected to have a high amylose content (CIRAD-CA records, 2003) but the prepared rice flour for this study was only found to have an intermediate amylose content. Peak gelatinisation temperatures (GT) of the materials ranged from 60.4°C to 78.7°C. Fidji (60.4°C) and Arelate (64.3°C) were thus considered as rices having low GT. Thaibonnet (72.2°C) was found to have an intermediate GT while Remy (75.7°C) and Suphanburi I (78.7°C) were found to have a high GT.

Table 8. Physicochemical properties of rice flours.*

Variety	Moisture content (%wb)	Amylose content (%dry starch)	Peak gelatinisation temperature (°C)
Arelate	9.7	16.5	64.3
Fidji	9.3	20.8	60.4
Thaibonnet	9.4	23.5	72.2
Remy	9.9	20.6	75.7
Suphanburi I	10.6	23.7	78.7

Source: CIRAD-AMIS-PAA records (2003)

3.2.1Preliminary study

On the first part of the parametric study, a preliminary study was conducted in order to validate the hypothesis that complexation and amylose retrogradation would play a critical role on the stability of rice noodles subjected to heat treatments. The idea was to produce some noodles using the traditional process (i.e. sheeted rice noodle) currently used in Asia and at the same time, characterise the samples to know whether our hypothesis is correct. The characteristics of the samples as determined by DSC analysis are shown below.

Table 9. Characteristics of stable and unstable sheeted rice noodles using Thaibonnet rice flour.

Sample	Stability after sterilisation	Thermal characteristics
RFT2*	Unstable	- gelatinisation endotherm was observed - amylose-lipid complex endotherm was detected with a peak temperature of 95°C
CFN**	Stable	- no gelatinisation endotherm was observed - amylose-lipid complex endotherm was detected with a peak temperature of 95°C

* sheeted rice noodle made from dough.
** sheeted rice noodle made from starch slurry.

As shown on Table 9, the unstable sample (RFT2) was observed to have a gelatinisation endotherm whereas the stable sample (CFN) did not show any gelatinisation endotherm. As such, our hypothesis about amylose retrogradation on stability was strengthened since the complete gelatinisation of starch as in the case of the stable sample (CFN) had played a role to produce amylose retrogradation. It was suspected that amylose and not amylopectin retrogradation that played a role on the stability of the sample since retrograded amylopectin melts between 50-60°C *(Mestres* et. al*., 1988).* The presence of a gelatinisation endotherm on the unstable sample (RFT2) simply means that not so much starch was gelatinised and therefore, less amylose molecules would tend to retrograde. With such result, it was further realised that starch in the flour should be as much as possible be gelatinised in order to be much involved in the formation of the stable structure. Our conclusion contradicts the findings done by *Resmini* et al*.. (1979). Resmini* et al*. (1979)* reported that rice pasta made with 7% pregelatinized rice flour already produced noodles with good quality than that with 100% gelatinized or raw rice flour. *Resmini et al. (1979)* further cited that increasing the proportion of gelatinized flour from 7% to 10-15% did not further improve the cooking quality and network compactness of the cooked noodles in his study.The conclusion drawn by *Resmini* et al*. (1979)* might be true for noodles intended for domestic use but not for noodles intended for heat treatments.

Furthermore, it was observed that both samples had amylose-lipid complex endotherms with a peak temperature of 95°C. The presence of such amylose-lipid complex endotherm was a good indicator since this endotherm is known to be classified as form I complex by some researchers *(Biliaderis and Galloway, 1989)*. This form I complex, as observed on the rice noodle samples, can be converted into a second form with a higher melting temperature through isothermal annealing close to the melting temperature (95°C) of such form I complex *(Biliaderis and Seneviratne, 1990)*. If the form I complex will be converted to a new form with a higher melting temperature (above 100°C), it would then be possible that the noodle would be more stable. With such observations, it was realised that more starch should be as much as possible be gelatinised so that more amylose could be leached out from the starch granule and can then be available to participate on amylose retrogradation and amylose-lipid complex formation.

3.2.2.1 Main part of the parametric study

The main part of the Parametric Study covered the observations on the produced extruded rice noodles using the five different raw materials (i.e. Arelate, Fidji, Thaibonnet, Remy, Suphanburi I). As shown below (Table 10), gelatinisation endotherms were observed on all control while no gelatinisation endotherm was observed on the rest of the treatments. This simply indicates that the native starch in the material was completely gelatinised.

Table 10. Gelatinisation endotherm in extruded flat rice noodles.

	Gelatinisation enthalpy (J/g)					Peak gelatinisation temperature (°C)				
	Arelate	Fidji	Thaibonnet	Remy	Suphanburi I	Arelate	Fidji	Thaibonnet	Remy	Suphanburi I
T0	6.4	6.7	9.1	12.2	11.6	69.7	66.2	72.8	75	76.7
T1-T4	*	*	*	*	*	*	*	*	*	*

* absence of gelatinisation endotherm.

An example of a gelatinisation endotherm (first peak) is shown below (Figure 6). The DSC thermogram shown below was from the control sample of Suphanburi I.

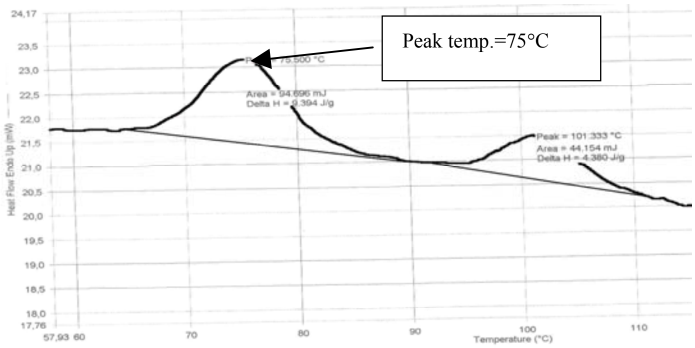


Figure 6. Gelatinisation endotherm observed on the control samples of extruded rice noodles.

3.2.3 Presence of amylose-lipid complexes

In model systems of solution-crystallized complexes with monoacyl lipids (i.e. fatty acids, monoglycerides, etc.), *Biliaderis and Galloway (1989 as cited by Biliaderis* et al*., 1993)* demonstrated the formation of two distinct polymorphic structures, depending on the crystallization temperature: Complex I with melting temperature (Tm) below 100°C and complex II with Tm above 100°C. Complex I, expected with rapid nucleation, predominates at low crystallisation temperatures (50-60°C). It is morphologically described by a random distribution of helical chains having little cystallographic register in the aggregated state. In contrast, complex II appears to have the structure of discrete crystallites and is the preferred polymorph at high crystallization temperatures (>90°C).

The presence of amylose-lipid complex was observed on all samples. An example of a DSC thermogram showing the two forms of amylose-lipid complexes formed on the extruded rice noodles is shown on Figure 7. The sample used is that of the complexation-treated sample with additive (T2) using Suphanburi I.

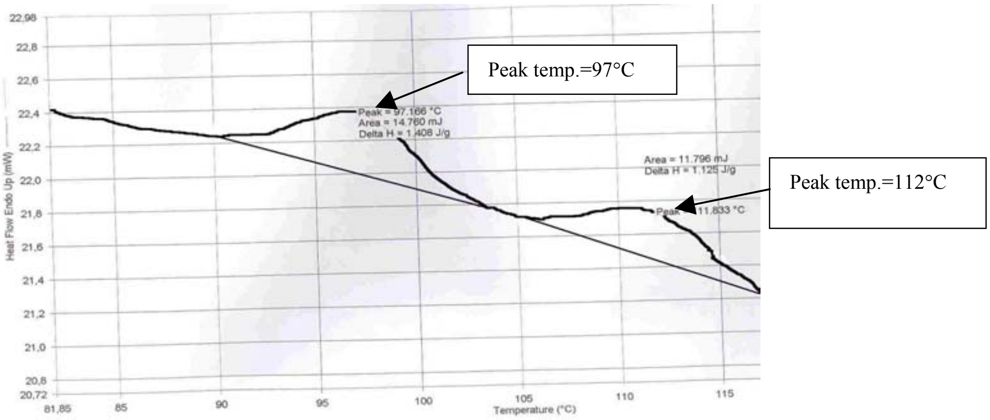


Figure 7. Two forms of amylose-lipid complexes formed on extruded rice noodles.

Transition temperatures of the formed amylose-lipid complexes are shown below (Table 11). All complexation and retrogradation–treated samples with additive (T2 and T4) showed two amylose-lipid complex endotherms. The effect was more pronounced on complexation-treated samples with additives (T2). On the 1st endotherm, transition temperatures varied from 88.8 °C (Suphanburi I T4) to 110.3°C (Remy T3). On the other hand, transition temperatures on the 2nd endotherm varied from 105.5°C (Fidji T4) to 112°C (Fidji T2).

Table 11. Transition temperatures* of the first and second amylose-lipid complex endotherm of extruded flat rice noodles.

Process	Variety									
	1st endotherm					2nd endotherm**				
	Arelate	Fidji	Thaibonnet	Remy	Suphanburi I	Arelate	Fidji	Thaibonnet	Remy	Suphanburi I
T0	95.2	92.5	95	95.2	94.7	-	-	-	-	-
T1	97.8	94.3	105.5	107.8	107.8	-	-	-	-	-
T2	97.2	96.5	96	96.7	97.2	111.8	111.9	111.8	111.3	112.3
T3	97.7	105	106.2	110.3	91.5	-	-	-	-	107.9
T4	96.7	96.6	96.2	97.2	88.8	108.3	105.5	106.4	108.2	107.2

* Transition temperature is expressed as °C

** absence of 2nd amylose-lipid complex endotherm

As observed on the 1st endotherm, the low GT rices (i.e. 64.3 °C for Arelate and 60.4°C for Fidji) showed in general the formation of form I complex whereas the intermediate to high GT rices (i.e. 72.2°C for Thaibonnet, 75.7°C for Remy, and 78.7°C for Suphanburi I) were able to produce more form II complex. The said observation agreed with the study done by *Biliaderis* et al*. (1993)* on parboiling of rice. Such results can be explained as follows. First, an absolute requirement for amylose-lipid complex formation is sufficient molecular mobility of the starch chains *(Biliaderis* et al*. 1993)*. Second, between the two polymorphs, Complex I is the kinetically preferred structure that is formed rapidly at relatively low temperatures *(Biliaderis and Galloway, 1989)*. In contrast, complex II is a thermodynamically favored structure (state of lower free energy than that of Complex I) and is formed at high crystallization temperatures. DSC data showed that steaming of the noodles was adequate to gelatinise the starch based on the absence of gelatinisation endotherms on T1 to T4 treatments (Table 4.10). In low GT rices, gelatinisation of starch occurred at low temperature thereby fostering the formation of form I complex. For the intermediate to high GT rices, much higher temperature was required to be reached before any substantial chain mobility occurs. At such high temperatures, formation of the more thermodynamically stable form of the complex II is favored. This is probably the reason why Thaibonnet, Remy, and Suphanburi I were able to produce form II complex at T1 (complexation-treated without additive) and T3 (retrogradation-treated without additive) treatments.

On the contrary, the form I complex observed on the control of the intermediate to high GT rice varieties (Thaibonnet, Remy, Suphanburi I) was probably the complex formed when the sample was heated during the DSC analysis or possible the complex formed during the gelatinisation of the starch slurry which was used as a binder during extrusion. The heating done during the DSC analysis and the heating done on the slurry might not be sufficient to convert the form I complex to form II complex. *Biliaderis and Seneviratne (1990)* found that the form I complex can only be converted into the second form with a higher melting temperature through isothermal annealing close to the melting temperature (95°C) of such form I complex. Since steaming was not applied on the control, it is therefore logical that only the form I complex was formed on the control of these rice varieties. Furthermore, the melting temperatures of the amylose-lipid complex (92.5 to 95.2°C) observed on all the control samples complemented with the study of *Chien* et al*. (1999)* who found that rice starch with 27.9% amylose had the onset melting temperatures of complexes from 93- 96°C.

When it comes on the T2 and T4 treatments of the intermediate to high GT rice varieties, it was observed that two endotherms were formed. The 1st endotherm showed only the form I complex whereas the second endotherm showed the form II complex. This result could be best explained by either of the following reasons: (a) due to the differences on the lipids present in rice and in additives, (b) due to insufficient time of isothermal annealing. In the case of additives, the form I complex found on the 1st endotherm might be attributed to the lipid naturally occurring in the rice whereas the form II complex found on the 2nd endotherm might be attibuted to the lipid in the additive used. This is because it is known that the transition temperature (or melting temperature) of the formed complex depends on the nature of the complexing agent and is affected by fatty acid chain length, unsaturation and the nature of polar head *(Stute & Konieczny-Janda, 1983; Biliaderis* et al*., 1985; Eliasson & Krog, 1985; Kowblansky, 1985; and Morrison, 1985 as cited by Eliasson, 1986)*. Since the lipids present in the rice flour used and in the additives (i.e. monoglycerides, high amylose corn starch) used differ, it is therefore possible to produce different type of complexes. Furthermore, steaming time might be another reason because it is known that form I complex can be converted to form II complex by isothermal annealing closed to the melting temperature of the form I which is 95°C *(Biliaderis and Seneviratne, 1990)*. The form I complex as observed on the 1st endotherm was not probably all converted into form II complex (as observed on the 2nd endotherm) possibly because longer steaming time might be required for the transformation to completely occur.

Furthermore, form II complex was not immediately produced on the 1st endotherm of T2 (complexation-treated with additive) and T4 (retrogradation-treated with additive) treatments of these varieties possibly because the additives used might had compete with the water in the system which is required for immediate gelatinisation thereby hampering the formation of complex II. Presence of additives therefore might had change the distribution of water in the system. Only, it must be noted that the latter two treatments (T2 and T4) were the only processes abled to produce the second endotherm where the form II complex was observed. The formation of the form II complex on such treatments was somehow enhanced by the presence of suitable agents (additives) favoring the formation of the complex.

The ability of the distilled monoglyceride (DIMODAN PH 200) used in this study to produce complexes agreed with the study of *Biliaderis* et al*. (1986 as cited by Biliaderis* et al*. 1993)* who found that monoglycerides are capable of producing the two forms (I and II). Also, *Guraya* et al*. (1997)* found that an emulsifier intended as a starch-complexing agent should have a low iodine value which is the case for DIMODAN PH 200. These were probably the reasons why the formation of amylose-lipid complexes was more pronounced on Complexation – treated samples with additive (T2). In the case of the high amylose corn starch, it is known by record that it has 0.2% saturated fat dry basis *(National Starch &Chemical, 2003)*. *Yamada* et al (*1988* as cited by *Zhou* et al., *2002*) found in maize starch that saturated fatty acids were preferentially complexed with the amylose. Such lipid present in the additive might therefore the possible reason why another endotherm was formed. It must also be noted that the high amylose starch used has a gelatinisation temperature of 90°C which in logic, may favor the formation of form II complex.

3.2.4 Presence of retrograded amylose

Eerlingen (1994) found that formation of Resistant Starch (RS) type III formed from retrograded amylose depended strongly on storage time and storage temperature. He concluded that the formation of RS in gelatinised starch can be considered as crystallisation of amylose in a partially crystalline polymer. According to *Farhat* et al. *(2003)*, the effect of temperature on crystallisation kinetics is best understood when considering its effect on the 2 main stages: the nucleation and the rate of propagation in the context of the glass transition (Tg) and the melting temperature (Tm). In the case of retrograded amylose system, nucleation is favoured at temperatures far below the melting temperature of the crystals (ca. 150°C), but above the glass transition temperature (ca. –5°C), while propagation is favoured under conditions far above the glass transition temperature but well below the melting temperature. *Eerlingen (1994)* further found that at a high storage temperature (100°C), resistant A-type crystalline structures were formed when incubated for several hours, while at lower temperatures (0 and 68°C), formation of B-type crystals was observed.

The presence of retrograded amylose was observed on all treatments. Retrograded amylose was observed as tiny filamentous birefringent structures under polarized light using a microscope. The presence of retrograded amylose on all extruded samples can be somehow explained as follows,: For the control samples, a gelatinised starch slurry was used to act as a binder in the noodles. The amylose molecules in this gelatinised part might have been converted to retrograded amylose since a 1st pre-drying step (75°C; 50-75% RH; 2 h) was applied prior to final drying of the samples. It can be said that amylose and not amylopectin retrogradation was the one favored in the pre-drying step since the drying temperature used is 75°C which is above the melting temperature of amylopectin. As mentioned earlier, crystallization (retrogradation) is favored between the glass transition temperature and the melting temperature of the polymer. Furthermore, the high relative humidity used (50-75 %RH) did not immediately removed the water in the system which is necessary for molecular mobility to occur.

For the other treatments (T1, T2, T3, T4), the presence of retrograded amylose can be explained as follows. Spraying of water on the samples and the two-step steaming process (1 hour followed by 15 min) would ensure that gelatinisation of the starch (necessary for amylose retrogradation) would be applied on the samples. Gelatinisation is necessary to occur so that the amylose in the granules could be leached out and could then formed a retrograded structure. The resting of the steamed samples for 2 hours at 4°C , then for overnight at room temperature, followed by the initial drying step of 75°C at 50-70%RH were expected to somehow help in amylose retrogradation. As mentioned earlier, the formation of retrograded amylose depended strongly on storage time and storage temperature. The resting of steamed noodles at 4°C and then at room temperature for several hours would then favor the nucleation stage whereas the initial drying of 75°C for 2 h would somehow favor the propagation stage. Also, it must be noted that resting the noodles at 4°C and then at room temperature would favor the formation of B-type amylose crystals whereas the 1st pre-drying step (75°C, 50-75%RH; 2h) would favor the formation of A-type amylose crystals.

3.2.5 Effect of variety and process

3.2.5.1 On visual aspect

Result on visual observation on the stability of the samples is shown on Table 12. Lowest score (0) corresponds to a perfectly stable sample whereas highest score (4) corresponds to a completely melted structure.

Table 12. Visual aspect of extruded flat rice noodles

Process	Variety***					PROCESS MEAN**
	Arelate	Fidji	Thaibonnet	Remy	Suphanburi I	
T0	4	3	3	3	2	3.0**d**
T1	4	2	1	2	0	1.9**b**
T2	3	1	2	4	2	2.5**c**
T3	4	1	0	1	0	1.2**a**
T4	3	1	1	2	0	1.6**b**
VARIETY MEAN*	3.6**D**	1.7**B**	1.4**B**	2.5**C**	1.0**A**	

*Means sharing the same capital letter are not significantly (α=0.05) different when compared among the variety.
**Means sharing the same small letter are not significantly (α=0.05) different when compared among the process. Yellow shade indicates lowest value while pink shade indicate highest value
*** 0,1,2,3 and 4 as perfectly stable, mostly stable , partially stable, mostly unstable, and completely melted.

Based on Analysis of Variance (ANOVA), the variety, process and interaction of the two factors are significant (α=0.05). It simply means that the variety, the process and their interaction had an influence on noodle stability in terms of appearance.

Comparison among means showed that among the variety, Suphanburi I produced noodles having the best visual aspect (1.0) whereas Arelate noodles were found to have the worst appearance (3.6). Also, it was found that noodles from Suphanburi I differ significantly from those made from Fidji (1.7) and Remy (2.5). Moreover, noodles made from Arelate (3.6) were found to be significantly different on the noodles made from the rest of the varieties. Decreasing amylose content also decreased the visual stability of the samples.

Among the process, it was found that the retrogradation-treated process without additive (T3) produced the best visual aspect (1.2) whereas the control (T0) produced the worst appearance (3.0) on the samples. Moreover, it was found that the effect brought about by retrogradation-treated process without additive (T3) differ significantly from retrogradation-treated process with additive (T4) and Complexation-treated process without additive (T1). Furthermore, the effect brought about by Complexation-treated process with additive (T2) was found to be significantly different when compared to the control (T0).

Based from the results, it can be concluded that the two retrogradation treatments (T3 and T4) and the complexation –treated process without additive (T1) had a positive effect on the visual stability of the samples. This can be reflected by their mean score of 1.2, 1.6, and 1.9, respectively which literally means "perfectly stable" and "mostly stable structure". On the contrary, the control (T0) and the Complexation-treated process with additive (T2) were shown to be significantly detrimental on the visual aspect of the samples. This can be reflected by their mean score of 2.5 and 3.0 which literally means "mostly unstable" structure.

The importance of the significant interaction between the variety and the process simply means that even if the noodle manufacturer used the right rice variety but if he did not use the right process, a visually stable noodle could not be produced. A good example among the treatments is the Suphanburi control (T0). Suphanburi I was found to be the best among the variety but when it was manufactured using the control process, the resulting noodle was found to be "mostly unstable" as reflected by its mean score of 2.0.

Multi--variate ANOVA statistics revealed that "Process" was the most influential factor on the visual characteristics of noodles. This can be justified by the fact that even the amylose content of Fidji (20.8) differ from that of Thaibonnet (23.5), still the visual aspect of the noodles made from these varieties did not differ significantly from each other (refer to Table 12). It therefore proves that it is the process which gave a more pronounced effect on the resulting visual aspect of the noodles.

3.2.5.2 On texture (stickiness)

Stickiness value (g.s) of extruded rice noodles are shown below (Table 13). High value corresponds to a very sticky material whereas low value corresponds to a less sticky material.

Table 13. Table of means for stickiness* of extruded flat rice noodles (α=0.05).

Process	Variety					PROCESS MEAN***
	Arelate	Fidji	Thaibonnet	Remy	Suphanburi I	
T0	367.6	132,8	73.0	138.1	67.3	155.8**b**
T1	182.2	112.6	49.7	72.0	7.6	84.8**a**
T2	109.8	60.0	24.5	0.1	24.1	43.7**a**
T3	245.7	101.1	25.5	45.0	3.4	84.2**a**
T4	134.9	49.7	20.5	18.3	0.1	44.7**a**
VARIETY MEAN**	208.0**C**	91.3**B**	38.7**A**	54.7**AB**	20.5**A**	

*Stickiness is expressed as g.s;; yellow shade indicates lowest value while pink shade indicates highest value.
**Means sharing the same capital letter are not significantly (α=0.05) different when compared among the variety.
***Means sharing the same small letter are not significantly (α=0.05) different when compared among the process.

ANOVA revealed that both varieties and process are influential on noodle stickiness(α=0.05). Comparison among means showed that among the variety, Suphanburi I havin the hihest amylase content was found to produce noodles which were the least sticky (20.5 g.force) whereas those from Arelate (havin the lowest amylase content) were found to be the most sticky (208.0g.force). *Chinnapha (2001)* studied the effect of amylose and amylopectin on rice noodle quality. He found that amylose retrogradation contributed to noodle structure and decreased stickiness and concluded that amylose mainly influences the 3-dimensional structure of rice noodles. This is possibly the best reason why Suphanburi I (having the highest amylose content on all varieties) was found to be the least sticky.

Among the process, it was found that complexation-treated process with additive (T2) produced the least sticky noodles (43.7) whereas the control (T0) was found to produce the stickiest samples (155.8 g.force). Only the control was found to be significantly different from the rest of the treatments. It simply means that all processes employed had made a positive effect on the texture (stickiness) of the noodles. The result further suggests that the distilled monoglyceride used (DIMODAN PH 200) had a significant influence on reducing the stickiness of the samples but not necessarily enhancing the stability of the noodles.

Multi-variate ANOVA statistics revealed that the more significant factor is the "Process". This can be justified by the fact that even the amylose content of Remy (20.6) differ significantly from those of Suphanburi I (23.7) and Thaibonnet (23.5), still the stickiness of the noodles made from these varieties did not differ significantly from each other (refer to Table. 13). It therefore proves that it is the process which gave a more pronounced effect on the resulting stickiness of the noodles.

3.2.5.3 On stability (total cooking loss)

The stability of samples (expressed in TCL) is shown in Table 14. High TCL value corresponds to the least stable sample whereas low TCL value corresponds to a stable sample.

Table14. Table of means for stability (expressed as %TCL) of extruded flat rice noodles (α=0.05).

Process	Variety					PROCESS MEAN**
	Arelate	Fidji	Thaibonnet	Remy	Suphanburi I	
T0	98.2	61.4	75.2	64.3	39.2	67.7a
T1	99.0	35.3	11.9	69.6	0.0	43.2**b**
T2	49.2	9.9	22.3	90.6	42.4	42.9**b**
T3	95.5	1.8	1.6	5.6	0.0	20.9**c**
T4	43.1	15.2	1.7	57.4	0.0	23.5**c**
VARIETY MEAN*	77.0**C**	24.8**A**	22.5**A**	57.5**B**	16.3**A**	

*Means sharing the same capital letter are not significantly (α=0.05) different when compared among the variety.; yellow shade indicates lowest value while pink shade indicates highest value.
**Means sharing the same small letter are not significantly (α=0.05) different when compared among the process.

Analysis of variance showed that the variety and the process used had made a significant effect on the stability of the noodles (α=0.05). Among the variety, Suphanburi I noodles were found to be the most stable (16.3%) whereas those from Arelate were found to be the least stable (77.0%). Noodle stability made from Suphanburi I, Thaibonnet (22.5%) and Fidji (24.8) did not differ significantly from each other but they differ from those made from Remy (57.5%) and Arelate.

Among the process, retrogradation-treated sample without additive (T3) produced the least cooking losses (20.9%) whereas the control (T0) produced the highest (67.7%). Retrogradation-treated processes such as T3 (20.9%) and T4 (23.5%) were found to produce a significant positive effect on noodles staility as compared to complexation-treated processes T1 (43.2%) and T2 (42.9%) and the control (67.7%). This implies that retrogradation and not amylose-lipid complexation had played a significant contribution on the stability of samples. The data obtained from the DSC thermograms supports this conclusion since the highest melting temperature among the amylose-lipid complex formed is 112.3°C. Since such temperature is lower than the sterilisation temperature used (121°C), it cannot therefore be expected that amylose-lipid complexation had influence the stability of the samples. Such amylose-lipid complex, however, would be beneficial for rice noodles to be subjected for pasteurisation (100°C) but not for sterilisation. Furthermore, retrogradation which had occurred in the samples could be attributed to amylose retrogradation and not on amylopectin retrogradation because amylose is said to be responsible for short term (less than 1 day) changes while amylopectin is responsible for the longer term rheological and structural changes of starch gels (*Zhou* et al, *2002*).

Multi-factor analysis of variance showed that the interaction between the two factors is significant (α=0.05). This implies that the resulting stability of the noodles does not come solely from the individual effect brought about by the variety or process but also depends on their combined effect. It simply means that the noodle manufacturer must choose the right rice variety and combined it with the right process so that a stable noodle having low cooking loss could be produced. A good example among the treatments is the Suphanburi complexation-treated sample with additive (T2). Suphanburi I was found to be the best among the variety but when it was manufactured using the T2 process, the resulting noodle was found to be have high total cooking loss as reflected by its mean score of 42.4%.

As mentioned earlier, all factors (i.e. variety, process, combined effect of variety and process) had a significant effect on the stability of the samples. However, when all factors were subjected to multi-variate ANOVA statistics, it was found that the most influential factor is the "Process". This result further implies that methods measuring amylose content are not really enough to predict stability of rice noodles since it is not solely the amylose content that affect stability but also more importantly the process.

Also it must be noted that among the variety, the results obtained from TCL followed the same trend on the results obtained from visual observation. In ranking, Suphanburi I was found to be the best, followed by Thaibonnet, Fidji, Remy, and Arelate. Increasing amylose content of the samples also increased their stability. Such result supports the findings of other authors that the high amylose flours have greater stability towards distintegration during cooking *(Juliano and Sakurai, 1985b)*. Such stability is attributed to the fact that amylose contains more intermolecular hydrogen bonding than amylopectin and thus can form hydrogen bonds with neighboring molecules and build-up a three dimensional network *(Glicksman, 1979)*. Since amylose is required to form a continuous matrix, Arelate, having lowest amylose content could not therefore be expected to be stable as reflected by its high cooking loss.

One interesting and very important findings in this study is that among the process, the trend obtained from visual inspection was not the same from that obtained in TCL. Complexation-treated samples without additive (T1) was found to be more visually stable than the complexation-treated samples with additive (T2), however, T2 samples had lower cooking losses than the T1 samples. This therefore implies that TCL should always be counter-checked with visual inspection because there maybe some noodles which may give low cooking loss (due to the effect of additive) but may not be visually stable. The low cooking loss of T2 samples as compared to T1 samples supports the findings of *Lai (2001)* about the effects of emulsifiers on the quality of rice pasta. She found that emulsifiers decreased the solubility of rice pasta in cooking water. *Kaur and Singh (2000)* also observed that addition of fatty acids decreased water-solubility in rice paste cooked for 30-90 minutes.

4. SUMMARY AND CONCLUSION

In the development of a simple test to measure stability of rice noodles subjected to heat treatments, it was found that the OB method was the simplest method capable of reflecting the condition performed in the industry on pasteurising or sterilising rice noodles. The OB method at pasteurisation and sterilisation conditions, being TCL as the main parameter, was found to be capable of discriminating a stable from a non-stable sample most probably because of its capability to reflect the imperfections on the noodle structure. Also, it must be noted that samples should be first evaluated in terms of their visual aspect since there maybe samples which are visually unstable but may give low total cooking loss. Furthermore, it was found that efficiency of TCL was high when testing stable samples than when testing unstable samples.

In the parametric study done on the stability of rice noodles, it was found that factors influencing a stable rice noodle include the variety, the process used, and their combined effect. Results showed that the higher the amylose content, the greater would be the stability of the noodle although rice varieties used in this study had only a maximum amount of intermediate amylose content. Processes intended to promote retrogradation were the one found to significantly affect noodle's stability than those processes intended to promote amylose-lipid complexation. The importance of the interaction effect between the variety and the process clearly indicates that it is not solely the variety or solely the process where the stability of the noodles depend but also on the combined effect of the two factors. Thus, in producing rice noodles resistant to heat treatment, the right variety (having intermediate to high amylose content) and the right process (intended to promote retrogradation) should be carefully chosen so that a stable structure could be formed. The result further implies that methods measuring the physico-chemical properties of a rice (i.e. amylose content, etc.) are not really enough to predict stability of rice noodles since it is not solely the variety that affect stability, but also more importantly the process. The data gathered in the parametric study further strengthened the capability of the developed method in evaluating the heat resistance of rice noodles that are to be subjected at pasteurisation (100°C) and sterilisation condition (121°C). This is mainly due to the fact that variety is not the sole influential factor on noodle stability.

The method and test developed in this study could now provide rice noodle manufacturers and exporters enough capacity to screen the rice noodle products that they intend to bring in the export market. The processes / technologies and the raw materials (e.g. rice varieties, additives) had somehow provided information about their role in defining the rice noodle quality characteristics that were examined. Rice noodle manufacturers and exporters will now have the right tool and enough knowledge for product evaluation and on choosing the right raw material and processes to be used for noodle production. Also, companies may now have enough information in producing stable rice noodles using a technology which can be easily and practically performed in the industry.

5. PERSPECTIVES

Additional research is suggested in making the developed TCL test to become quicker since TCL determination takes about 2 days to complete the drying of the samples. Also, the development of some rapid predictive tests capable of reflecting the imperfections in the noodle structure is also suggested. Sensory and textural tests on the produced samples may also be determined in order to characterise the eating quality of the produced samples. Process optimisation on the process used for both sheeted and extruded nooldes is also suggested for industrial profitability. Optimisation study on the use of high-pressure treatment on rice noodles is also suggested since it was found in some studies that the initial heating temperature used to gelatinise the starch may increase the melting temperature of the formed amylose crystallites (i.e. retrograded amylose). Furthermore, characterisation of the retrograded amylose component found in the stable noodles may also add to the present knowledge on amylose retrogradation. Moreover, determination of the glass transition temperatures of the noodles after steaming is also recommended so that the noodle manufacturer may know what exact temperature he can store his rice noodles to facilitate amylose retrogradation. Other possible studies on the retrogradation-treated rice noodles may be explored since retrograded amylose produced in the process was found to act as dietary fiber does and therefore may be beneficial to people suffering from diabetes, hypertension, unmanageable body weight, etc.

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