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STRENGTHENING OF THE TECHNOLOGICAL CAPABILITY
OF THE THAI PACKAGING CENTRE
DP/THA/87/019
THE KINGDOM OF THAILAND

Technical report: The shelf-life estimation
of fresh and processed food*

Prepared for the Government of Thailand
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of I. Varsanyi,
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Vienna

* This document has not been edited.

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I. ABSTRACT

A. Title and number of the project

The title of the project is "Strengthening of the technical capability of the Thai Packaging Centre", and the number is DP/THA/87/019/B/01/37. The duration of the project is one and a half years and it started in the middle of 1990.

The primary function of the project is to build up the institutional capacity of the Thai Packaging Centre (TPC) to transfer latest results of packaging science and technology into the national production and marketing enterprises concerned. To meet effectively this goal, the project inducts TPC into applied research of laboratory testing of different packaging materials, of shelf-life determination of fresh and processed foods, and of marketing-oriented packaging design in support to the packaging manufacturer and user enterprises .

B. Objective and duration of the activity

The main objective of the activity is to stiengthen the capability of TPC staff in the field of planning, realizing and evaluating research and development programmes for shelf-life determination of packed fresh and processed food regarding to the requirements of the Thai food industry, including export marketing.

In the frame of activity some fresh and processed foods were investigated, which (Rambutan and spices : nut meg, clove, white pepper) were chosen by counterpart, for shelf-life estimation in consumer and retail packaging. For knowledge improvement of staff,lecture was given on the basic theory of food determination and shelf-life estimation of fresh and processed food. A review of scientific and technical literature was prepared for the request of counterpart about the interactions between the packaging materials and packed foods. In addition four other materials were prepared as manuals to strengthen the scientific and technical capability of TPC. They appear - among others - in the annexes of the report.

The expert activity started om 17 June 1990, with a duration of four months.

C. Main conclusions and recommendations

The main conclusion is that the development of fresh and processed food packaging is not only the one of basic interests of the packaging manufacturer and user industries but also important for Thailand because it is a way to increase the export potential of the country. In this situation the Thai Packaging Centre (TPC) as a scientific and practical background of development has a key position, therefore the strengthening of their capability is necessary for the progress of packaging.

The main recommendations gained on the basis of experiences could be summarized as follows.

Considering the equipment of TPC, it may be stated that the instrumentation of the Centre is fit and modern but a few instruments are missing which would be important not only for research and development but also for quality control. To meet the requirements of the food and the packaging industries, further more to adapt the latest results achieved in other countries particularly in the field of food safety, it is recommended to obtain a Gas-Chromatograph (GC) and/or a High-Performance-Liquid-Chromatograph (HPLC) to detect the residues of solvents, adhesives and other auxiliaries of packaging material and container procedures, including the printing, too. The application of head-space technique would be also possible by the instruments recommended to follow the quality changing of packed fresh and processed foods for shelf-life estimation, especially in the case of the modified atmosphere packaging (MAP). The head-space technique would also be a tool to determine the aroma permeability of packaging materials and containers for foodstuffs with high volatile oil content like spices.

The problems of corrosion are very important from the aspect of food safety, therefore it would be recommended to develop the activities of TPC in this field and to test the quality of coating, including the stickness and protectivity of lacquers and varnishes of metal containers, according to national and international standards and rules. The GC and mostly the HPLC technique would also be suitable to analyse and define the interactions between the packed food and packaging material.

Since the irradiation (light) causes significant quality changing of foods, it is recommended to obtain sufficient instruments to determine the light (radiation) barrier property of packaging materials and containers. The instrument would be fit to measure not only the intensity and energy of radiation (light) transferred but also to determine the spectra of light inside the package. It would also be suitable to measure the porosity of aluminium foils and the quality of metalic layer of coated materials. Furthermore it is recommended – besides the instrumentation suggested – a well trained staff to utilize the instruments on wide range and to improve the expert services of TPC.

The shelf-life estimation activity of TPC demands a sufficient storage capacity with controlled temperature (the accuracy would be maximum $\pm$ 2K), humidity (maximum $\pm$ 2.5%) and with computerized illumination. The present storage capacity does not give possibility for medium or long-term shelf-life experiments. (Presently the thermostates of conditioning were used for short term shelf-life investigions.) In addition the shelf-life estimation needs chemical, physical, biological – including microbiological – and sensoric analyses to follow the quality changing of foods. The measurements of that require both adequate instrumentation and individual experience. Regarding the possibilities it is recommended to harmonize the shelf-life estimation activities of TPC with other departments, sections or laboratories of the Thailand Institute of Scientific and Technological Research (TISTR) and to organize permanent and/or ad-hoc teams for the quality changing tests of fresh and processed foods.

The comprehensive testing of packaging materials and containers would be recommended because it would also give a good opportunity of TPC to develop co-operations with the packaging manufacturer and user industries, and in addition to establish or improve liaisons with other institutions, laboratories on national and particularly international level.

Strengthening the liaisons with manufacturer and user industries is also recommended to develop the information services of TPC using a computerized data bank. The work started with the PACKDATA DATABASE but it would be useful to collect technical data about the main parameters of industrial products first from home and later from foreign firms.

The shelf-life estimation demands standardized test methods and standards of products both for packaging materials, containers and for fresh, processed foods. The improvement of standardization would be very important and therefore highly recommended. The up-to-date standardized test methods give an excellent base for quality control and quality development.

II. CONTENTS

III. INTRODUCTION

A. Background

The importance of packaging has been recognized by the Government of Thailand as noted in the Fifth and in the Sixth Development plan (1987-1991) by the governmental authorities, therefore the Thai Packaging Centre (TPC) has to strengthen its capabilities to transfer modern packaging technology into the national production and marketing enterprises concerned. The one of the project purposes is to strengthen the capability of TPC staff on the planning and implementation of applied research and development programmes relevant to the needs of packaging manufacturer and user industries including the exporting community, as well as on interpretation of related laboratory testing results and subsequent elaboration of advice to the concerned parties. (The list of staff, including the field of education and the status is attached as Annex 1).

The functioning of project started in the middle of 1990, according to the project document DP/THA/87/019. The duration of project is one and a half years,and the expert's mission started on 17 June 1991 and was completed on 16 October 1991.

B. Objectives of the activity

The objectives of the activity being reported on is identical with the duties stipulated in the job description (DP/THA/87/019/11-04/j-13320). The counterpart team of expert was the staff of Research and Development Laboratory on the application of laboratory test techniques to follow the quality changing of the packed fresh and processed foods and foodstuffs, and on the evaluation of results achieved. The products – as models – were selected by the Head of R&D Laboratory in harmony with the National Project Co-ordinator (NPC) as well as the packaging materials and containers were chosen regarding to the local possibilities. The expert worked out a complete pre-test and test program of packaging materials and of packed products including the sampling plan, to estimate the shelf-life of packed foods and to determine the effects of packaging on the quality changing of packed products. For the request of counterpart the principles of shelf-life investigation programmes were worked out by the expert, giving practical methods for shelf-life estimation. In addition for the mathematical statistical analysis of experimental data a booklet was prepared by the expert for shelf-life estimation of different agricultural and industrial products.

Similarly, for the request of counterparts,lecture was given by the expert weekly from 4 July to 28 August 1991. The topics of lectures were selected from the field of the food and the packaging science and technology. It was an explanation of basic theory of deterioration and shelf-life estimation for fresh and processed food. The topics of lectures cover a post-graduate course on University level in accordance with the international practice. The counterpart has also asked for an international review of literature about the relevant fields of the food and the packaging science and technology to improve the knowledges of the staff.

The expert also took part in some of the actual experiments with theoretical and practical advices.

The objectives of expert activities were not revised and the target attained.

IV. ACTIVITIES AND OUTPUTS

A. Main duties

The main duties of Job Description and the objectives of activity being reported on are as follows:

1. Work plan elaboration for shelf-life determination of fresh fruits and processed foods chosen by the counterpart
2. Packaging design for retail and consumer packaging
3. Test programme for food and packaging
4. Elaboration of practical methods for shelf-life analysis
5. Objection analysis of packed fresh and processed food
6. Elaboration of mathematical statistical analysis of experimental data for shelf-life estimation

7. Lecture on shelf-life estimation of foods and foodstuffs

8. A review of scientific and technical literature about the interaction between the food and the packaging material

9. Recommendations to the Government for further actions

B. Technical activities

The technical activities were arranged according to the Job Description and to the request of counterpart, as they are following.

1. Shelf-life determination

(Paras 1-6 of Main duties and Job Description, respectively)

a. Work plan for shelf-life determination

Co-operating with the counterpart authorities the research and the test – including pre-test – work plan was worked out for shelf-life determination (Annex 2) regarding to the local and the export marketing of chosen products, to the possibilities of the TPC, to the relevant recommendations and standards, and to the international laboratory practice.

Rambutan was chosen by the counterpart for a model of non-processed fruits and vegetables in consumer and in retail packaging. For shelf-life determination of Rambutan a detailed work plan was prapared and it contains the aspects of fruit selection, the storage conditions, the sampling programme, the retail and the consumer packaging design, the test programmes of Rumbutan and the packages, the evaluation of tested values, and the shelf-life estimation of Rambutan (Annex 3).

For the adjustment of appropriate storage conditions in the laboratory of the TPC, an investigation was carried out to register the degree of temperature and relative humidity from harvesting till export marketing (Annex 4). The chosen parameters of storage conditions are stipulated in the work-plan for shelf-life determination of Rambutan.

Rambutan is not a standardized fruit, therefore a manual was prepared on the base of technical literature (Annex 4) and it contains the main aspects of Rumbutan packaging for the selection of the most significant properties regarding to the shelf-life estimation.

For the reduction of mechanical effects during the transportation and distribution of packed Rumbutan a recommendation was prepared about the inserts and cushioning materials and in addition about tests of retail and transport packaging on the base of Manual on the packaging of fresh fruits and vegetables, published by the International Trade Centre in 1988 (Annex 5).

The list of recommended standards was also worked out for the test of Rumbutan packaging materials (Annex 6).

Three spices, in ground (powder) form, were chosen as models of processed foods and foodstuffs for shelf-life determination in consumer packaging. With regard to the requests of counterpart a detailed work plan was prepared for shelf-life determination of spices and it contains the main aspects of spice selection, the parameters of storages, the sampling programme, the packaging design, the test programmes of spices and packages, the methods of tested values evaluation, and the shelf-life determination of spices (Annex 7).

The list of standards recommended was prepared for shelf-life estimation of packed spices (Annex 8). It includes standards to follow the quality changing of spices and standards for packaging material tests.

For the request of counterpart a manual was prepared to introduce a practical way of shelf-life estimation (Annex 9). It contains the main causes and the main sources of food quality changing, the analysis of quality changing during the processing and the storage, the method of shelf-life declaration, furthermore the methods of objection analysis of the packed fresh and processed foods, including the conclusions for improvement.

The shelf-life estimation needs some mathematical statistical calculations to select the most rapidly changing properties of stored product, to predict the critical time of storage, and to optimize the parameters of packaging regarding to the storage circumstances. For that purpose a manual was also prepared to promote the application of the mathematical statistical analysis of experimental data for shelf-life estimation (Annex 10). The recommended steps and equations of data analysis form two groups; one is the data analysis of tests, the other one is the shelf-life estimation.

b. Realization of work plan

- Pre-tests for shelf-life estimation of Rumbutan

Heat treatment of Rumbutan was carried out (dipping in hot water 70°C for 5 min., 80°C for 0.5, 1.0, 1.5 min., 90°C for 0.5, 1.0, 1.5 min. and 100°C for 0.5, 1.0, 1.5 min., resp.) to try to reduce the activities of microorganisms on the surface of fruits. Based on the results, we stated that the heat treatment did not influence significantly the hygienic state of fruits. It is necessary to mention, that the surface investigations were carried out by visual observation only, as the TPC has neither magnifying glass nor microscope.

Storage test was arranged of consumer packaging in three different types of packs on 14°C temperature during 14 days and on 30°C temperature during 7 days.

The effect of temperature and packaging was investigated by sensory method on the shelf-life of Rumbutan. The water absorption and the water absorption capacity of packaging materials was measured by gravimetric method with the scales of laboratory. The water vapour, oxygen and carbondioxid permeability was tested by barometric method with Lyssy equipment in the laboratory.

For the investigation of colour changing of Rumbutan we formed 12 grades of colour shade – from light yellow to dark red – and we made photos to fix the grades of colour. The series of pictures was the etalon for determination of colour changing.

Evaluating the results of pre-test we could state that 5-8 colour grade is the best for consumer and retail packaging. The paper box wrapped on four sides with shrinking polymer foil is the best for consumer packaging. In the case of retail packaging we could not state significant differences between the packages. The relative rank of packages was the following: present form (paper-carton box) covered with perforated foil inside; present form with carton inserts; and present form.

For the qualification of polymer foils, spectrogrammes were prepared in Infra Red range. It was stated by the spectra of foils, that the shrinking foil is a poly(vinyl chloride) – poly-(vinylidene chloride) copolymer, the stretch foil is a poly-(vinyl chloride) polymer, and the perforated foil is a poly-propylene polymer. The spectra of polymers were made in another section of TISTR.

- Test for shelf-life estimation of Rambutan

The work plan for shelf-life determination of Rambutan was minimized because the harvesting season of Rambutan went over in this part of the country and the new samples of fruit were obtained from other part of Thailand, approx. 600 km distant. Other problem was the very limited storage capacity, therefore the investigation of retail packages on 22 °C and on 30 °C temperature, furthermore the experiments of consumer packages were cancelled.

According to the work plan of Rambutan shelf-life determination on 18 days storage was realized and the sampling was in every 3rd day. The packaging was (A) present form, (B) present form wrapped inside with perforated polypropylene film, (C) present form with insert. Regarding to the maturity of fruit we formed two groups, 2-8 and 4-5 colour degree, respecitvely. For the shelf-life determination of Rambutan the following parameters were measured : overall acceptance of one pack, detailed acceptance of packed fruit (points are : 1 no change, 3 light defect, 5 medium defect, 7 unacceptable) by the observation (eyes) of open panel (the number of panelist was 3-7 from time to time). The weight loss (absolute and relative) of fruit was determined by gravimetrical method. The vitamin C content and the total sugar content changing of stored Rambutan was measured in other department of TISTR. The packaging was also investigated, the water absorption (absolute and relative) of packages and moisture content of packages by gravimetric method.

The results received are in Part c.

- Shelf-life estimation of spices

The realization of work plan worked out for shelf-life investigation and estimation of three spices packed in different containers has been neglected because many unexpected difficulties have risen up in the preparation period of experiments.

The most serious problem was the insufficient storage capacity of TPC not only for the long term but also for the short and medium term storages. The other unforseen difficulty was to purchase suitable plastic closures for glass bottles and plastic coated packaging material for pouches. The lack of analytical instruments was a further difficulty to follow the ratio of components changing, first of all in the volatile oil components' ratio during storages to select the critical properties of spices for shelf-life estimation.

Since the efforts to clear away the problems needed a lot of time and energy, it was decided by NPC to neglect the shelf-life investigations of spices and to study the shelf-life estimation method of Rambutan as a food model in very detail.

c. Results

On the basis of pre-test results of Rambutan it can be stated that the fruits with 5-8 colour grades have the best storability.
The fruit selection according to hygienic state is not possible, therefore the elimination of different micro-organism-born infections needs further research by plant pathologists.

The consumer packaging of Rambutan requests also further investigations first of all with thinner shrinking poly(vinyl chloride)-poly(vinylidene chloride) co-polymer films to protect the fruits against water content losses and infections. The card-board box with insert shows the best solution for consumer packaging of 6-18 fruits.

Evaluating the results from the aspect of storage circumstances it is recommended to use a lower temperature than 14 °C , the 8 °C - 12 °C seems to be effective for minimum two week shelf-lite. In that packaging form the light effect is negiectable.

The results of retail packaging tests emphasizes the importance of homogeneous maturity of packed fruit, because the inhomogeneity increases the deviation of main values, including the shelf-life. The 2-8 colour quality practically did not show differences between the packages, but the 4-5 colour grade showed a significant effect on the package.

Since the homogeneity of measurments was acceptable, all the data were used for shelf-life estimation. The curve fitting was made in the function of storage time and it can be stated in harmony of theory that the weight loss of fruit is linear. The quality changing of Rambutan is also linear, which is an unexpected result of investigations.

The critical value of quality changing gives some problems. If we calculate with 33.33% of deterioration then the shelf-life of packed fruit is about 9 days. If we use 50% of deterioration limit, which is possible in case of fresh fruits, then the shelf-life is 12 ± 1 day on 14 °C degree. Therefore it is very important to consulte with retailers, with special regard to the circumstances of selling.

Analysing the results of three different packages for 4-5 colour grade we may conclude the present form with perforated film (B) is the best one (the value of correlation coefficient, b = 8.69) the second is the present form (A), the b = 9.29, and the third is the present form with insert (C), the b = 10.54. The results of weight loss of fruits ensure the mentioned conclusion. The weight loss of fruits packed in (B) is 36.3 g, in (A) is 67.0 g and in (C) it is 82.1 g during 12 days.

From the aspect of packaging material water absorption, the three variations did not show important differences. The time of saturation is 6 days in case of (A) and (C), and 7-8 days in case of (B), respectively.

The accuracy of shelf-life estimation is good because values of r (correlation coefficient) are 0.9129 - 0.9298. Similarly the accuracy of fruit weight loss estimation is excellent because the r values are 0.9936 - 0.9959.

If the results of chemical analysis do not contradict the above mentioned shelf-life estimation based on open panel observation, then we can declare the shelf-life of Rambutan packed in 1 kg unit and in corrugated card-board boxes wrapped inside perforated film is 12 ± 1 day on 14 °C degree. For shelf-life extension further investigations are necessery with different packages and storage circumstances.

2. Lecture on shelf-life estimation of foods and foodstuffs
(Para 7 of Main Duties and Job Description, respectively)

A series of lectures were given weekly – 2 hours in the morning from 4 July to 28 August 1991 – for the members of the counterpart team. The topics of lectures were constructed regarding to the request of counterpart, and they were selected chapters of the packaging and of the food science and technology, respectively.

The main target of lecture was to acquaint the practice and the theory of shelf-life estimation of fresh and processed foods and foodstuffs. The main subjects of lectures were the characterization of food and its methods, the behaviour of relatively stable and changing attributes of food, the mechanism and kinetic of quality changing as well as the factors influence the quality including packaging, the methods of shelf-life estimation of fresh and processed food, and lastly the possibilities of shelf-life extension with special regard to packaging. The topics of lectures cover a post-graduate course on University level. The scheme of it is in Annex 11.

For better understanding two other materials were worked out; one is a recommendation to analyze the experimental data received of shelf-life estimation (Annex 10), other one is a general approach to follow the quality changing and select the critical property of packed food, in addition to structure and the method of quality control, and finally the principles of objection analysis (Annex 9).

3. A review of relevant scientific and technical literature
(Para 8 of Main Duties and Job Description, respectively)

The shelf-life estimation of fresh and processed foods is based on the research and development results both of the food science and technology, and of the packaging science and technology. Consequently the international technical literature is very wide and very rich because it includes micro- and macrobiological studies, enzyme analysis, in addition polymer micromorphology, mechanical, physical experimental analysis and many others.

The basic idea of review preparation was to present literature about identification and determination of interactions between packed foods and packaging materials which have direct or indirect effect on the quality. Of course the list of citations is not complete but it creates a good fundament for further researches of TPC technical staff (Annex 12).

C. Other activities

The contact searches and establishes important part of expert activities, which help to learn and understand the problems of relevant fields. Annex 14 shows the list of contacts which represents at same time the main sources of information and experience received both from the food processing and packaging manufacturers and users, and from the shipping and marketing representatives.

The factory visits have given opportunities to know the used technologies and quality control methods. The seminars and other meetings or events were the places of discussions and experiences exchanging. Consequently it may be stated that the contacts listed have contributed significantly to the success of the mission.

V. RECOMMENDATIONS FOR FURTHER ACTION

1. Further improvment of TPC activities in the field of fresh and processed food packaging to promote the marketing, particularly in foreign countries.
2. Collaborating with the packaging manufacturer and user industries, organize and launch a systematic and regular test programme of packaging materials, containers and auxiliaries as well as packages according to the national and international standards and regulations.

3. Depending on the financial possiblities, complete the equipment of TPC for strange material analysis by Gas-Chromatograph and/or High-Performance-Liquid-Chromatograph. The instruments give also possibilities of head-space techniques to follow the quality changing of packed products.

4. An adequate instrument would be necessery for light barrier properties of packaging materials and containers testing in the range of Ultra-Violet, Visible and Infra-Red.

5. It would be important to obtain a surface microscope for identification of defects and faults of packaging materials and packs, furthermore of printing quality.

6. Improvement of research and development activities of TPC is recommended in the field of modified atmospher packaging for shelf-life extension of fresh fruits, vegetables, including mushrooms, and in addition of fresh and processed foods.

7. For development of safety food it would be important to intensify both the activities of anti-corrosion research and test, and the investigations of coating systems and materials like lacquers, paints and varnishes.

8. The instrumentation recommended requires more trained staff which involves enlargement of TPC advisory services.

9. The improvement of information exchange would be wished by computerized data bank for strengthening the co-operation between institutions and industrial branches and export firms, respectively.

10. Action programme elaboration would be wished for standardization of test methods and product quality, regarding the increasing demands of domestic and export marketing.

11. The shelf-life determination needs a relatively large thermostated storage capacity, particularly the long term (more than 6 month) investigations, therefore it would be important to increase it in the TPC.

12. The international programmes of safety food and of healthy food call the attention of packaging from the aspects of nutritive value degradation and of strange material content increasing in packed products. It would therefore be adviseable to connect them with the programmes on national level, and improve the research and development capacity of TPC, with special regard to the demands of export markets.

13. It would also be important to improve the advisory services of TPC preparing the staff for objection analysis related to the domestic and the export marketing, respectively.

14. The protection of consumer interests is one of the most important duties of the State, therefore the shelf-life determination with objective methods would be an organic part of activities on institutional level. The establishment of an independent Unit (Department) would be useful for shelf-life estimation of fresh and processed foods in the future because tests and analyses of packaging and food needs different equipment, individual knowledges and experiences. The Unit (Department) would contain – in the first phase of three, in the second phase of four – special groups as it follows:

   - Food analysis. To follow and determine the quality and quantity changing of significant components of food and foodstuffs (e.g. rancidity, volatile oil composition, aroma); the nutritive and biological value (e.g. essential amino acids, vitamins, lipids) in the first phase with instrumental methods, later with in vitro and in vivo methods; and sensory properties (e.g. taste, colour, odour).

   - Physical – chemical analysis. To follow and determine the optical properties changing of food (e.g. colour, light absorption, Near Infra Red transparency); the water content changing (adsorption, desorption) including the rehydration behaviour of dried products; the pH value changing; the changing of rheological properties (e.g. firmness, elasticity, chewing property).

- Food biology. In the first phase microbiology for investigation and determination of hygienic state of foods, in the second phase the application of biological methods for food analysis, to follow the biological properties changing of fresh and processed foods. The application of enzyme tests would be also implemented in the first phase.

The staff of Unit (Department) would consist of 11 qualified analysts, with more than 8 years experience and of 16 qualified technicians with more than 5 years experience. The estimated cost of equipment is 450000 USD in the first phase and 250000 USD in the second phase, respectively. The cost of centralized computerization of data registration and evaluation is not included.

15. The environmental protection is an important aspect of packaging design, therefore it would be one of the main objectives of TPC to intensify the activities in this field.

VI. CONCLUSION

The post-harvest losses reduction and the shelf-life extension of fresh fruits and vegetables, as well as the ensurance of nutritive value and of sensoric properties of processed foods are the main tasks and duties of packaging. Therefore the common efforts of the Thai Government and UNIDO are very actual and useful, which has realized with others in the project "Strengthening of the technical capability of the Thai Packaging Centre", all that more because a very significant part of national incomes originates from fresh and processed food production and export, respectively. Consequently the shelf-life determination by objective test methods is basic interest of food producers, manufacturers and exporters.

The improvement of TPC technical staff capability on the planning and implementation of applied research and development programmes relevant to the shelf-life determination as well as on the correct interpretation of laboratory testing results was the main target of the expert's mission. On the basis of his work plans realized – as the sampling and the test programmes, packaging design, interpretation of shelf-life estimation, and of recommendations worked out – including mathematical statistical methods, and objection analysis, furthermore of his other activities to improve the capability of TPC technical staff, as the lectures and the review of scientific and technical literature, it may be stated that the counterpart team got acquainted with the methods of shelf-life estimation.

Nevertheless problems have arisen which influenced the fulfillment of investigations planned – as the lack of thermostated storage capacity of TPC, the lack of food analytical equipment and microbiological test facilities, furthermore the lack of time to obtain the polymer coated paper and the plastic closure of glass bottles for storage tests of spices – but they did not cause essential changing of the programme. It is unquestionable that the capability of the staff and the equipment of the Thai Packaging Centre is suited for packaging material and container test, but if it would be completed with a few recommended instruments – for light transparency test, for corrosion test, for solvents and other residues test – than it could expand investigations and tests on consumer and retail packaging.

The success of an expert mission always depends on the support received. Therefore I have to express my thanks for the information and help of UNIDO authorities - the Chief of the Packaging and Printing Industries Unit, Engineering Industries Branch (Vienna), Mr. N. Ramm-Ericson, Country Director (Bangkok), Mr. J. Nelis, Programme Officer (Bangkok); for the cooperation and assistance of Mr. Santhad Rojanasoonthon, Governor, Thailand Institute of Scientific and Technological Research, Ms. Amornrat Swatditat, Director, Thai Packaging Centre, and National Project Co-ordinator, Ms. Anchalee Kamolratanakul, Director, Research and Development Laboratory, and of all the members of counterpart team and staff of TPC. Of course the list is not exhaustive in view of all the colleagues who gave assistance and help but their efforts are reflected in the results achieved.

ANNEX 1

Thai Packaging Centre Staff

Name	Field of Education	Status
Director		
1. Miss Amornrat Swatditat	Food Science, Grain Science	P
R&D Lab		
2. Mrs. Anchalee Kamolratanakul	Chemical Engineering	P
3. Mr. Siriphong Pattanavibul	Horticulture	P
4. Mr. Somsak Chaimongkol	Agrononomy, Agriculture	P
5. Mr. Supoj Pratheepthinthong	Material Science	P
6. Miss Pattra Maneesin	Food Science	P
7. Miss Chavee Sribubpa	Agriculture	T
8. Mr. Anant Thephasdin Na Ayudhaya	Physics	T
9. Mr. Panom Tanawan	Art and Craft	T
10. Miss Teerarut Mookto	Biotechnology	T
Testing Lab		
11. Mr. Sakkhee Sansupa	Chemical Engineering	P
12. Mr. Phaisak Anannukul	Chemical Engineering	P
13. Mr. Chainarong Suwannawong	Electrical Engineering	P
14. Miss Amprang Kaenthai	Certificate	T
Training & Promotion Lab		
15. Mrs. Mayuree Paklamjeak	Food Technology	P
16. Mrs. Bussakorn Praditniyakul	Economics	P
17. Mr. Parinya Kamsathorn	Economics	P
18. Miss Kanjana Dummananda	Food Technology	P
19. Mr. Chaiwoot Kethlim	Art Education	P
20. Mrs. Sudaporn Kreethatorn	Business Administration	P
21. Mr. Vijarn Puangchingngam	Certificate	P
22. Miss Ubonphan Bunsamran	Certificate	T

Note : P = Permanent staff

T = Temporary staff

ANNEX 2

WORK PLAN

of Expert in processed food packaging for Strengthening of the Technological Capability of Thai Packaging Centre (DP/THA/87/019/11-04/J-13320)

Co-operating and in harmony with the National Project Co-ordinator, the work plan was worked out to complete the duties which are stipulated in Job Description as follows.

1. Shelf-life determination of Rambutan

1.1 Pre-tests for Rambutan packaging and shelf-life determination

- Heat treatment of Rambutan
  - 70°C 5 min
  - 80°C 0.5, 1.0, 1.5 min
  - 90°C 0.5, 1.0, 1.5 min
  - 100°C 0.5, 1.0, 1.5 min
- Storage test for 7 days in 30°C and 14°C
- Water absorption capacity of carton-paper
- Water vapour, O_2, CO_2 permeability of the stretch and the shrinking foils

1.2 Shelf-life determination of Rambutan

- Fruit selection
  - 3 groups, 6 grades
  - 2 groups, 2 grades for reference
- Storage conditions
  - Temperature : 30°C, 22°C, 14°C
  - Relative humidity : 85%
  - Light : in dark
  - Storage time : 18 days
- Sampling programme
  - For fruit : every second day
  - For packages : 9th and 18th day
- Packaging design
  - Retail packaging (1 kg, cca 30 fruits)
    - Present form
    - Present form and inside perforated polythyere foil for fruit wrapping
    - Carton box with insert

Consumer packaging (6 fruits, cca 0.2 kg)

Paper box with insert overwrapped with perforated film

Paper box with insert overwrapped with stretch foil

Paper box with insert wrapped on four side with shrinking film

- Test programme

Fruit test

Instrumental measurements

Sensory test

Hygienic test

Packaging test

Retailer packaging (mechanical tests)

Consumer packaging (mechanical and physical tests)

- Evaluation of measurements (for fruit and packaging)

Data analysis

Selection of crifical property(ies) of fruits

Curve fitting (of quality changing)

Comparison of curves - optimization

Shelf-life calculation and estimation of rambutan

Curve fitting accuracy (error of estimation)

- Conclusion

2. Shelf-life determination of spices

2.1 Pre-test of packaging materials

Water vapour and oxygen gas permeability of combined packaging material

Barrier behaviour of closure

Light transparency measurements

Mechanical test of foils

Sealing optimization

2.2 History of ground spices including the hygienic aspects

2.3 Shelf-life determination of spices according to the packaging

- The selected spices are : nut meg, clove, white pepper in ground (powder) form

- Storage conditions
  - Temperature : ambient (cca 30°C), 10°C
  - Relative humidity : registration during the storage, without control
  - Light : in dark
  - Storage form : separately and in retail packaging
  - Storage time : 24 months
- Sampling programme
  - For spices : every third month
  - For packages : 6th, 12th, 24th month
- Packaging design
  - Glass bottle (brown) with glass cork, 50 cm^3 (reference)
  - Glass bottle (transparent) with plastic closure, 50cm^3
  - Sachet (plastic + Alu + plastic foil) printed, for 20 g spice, cca 10 x 15 cm
  - Sachet (coated paper + plastic foil) printed, for 20 g spice, cca 10 x 15 cm
- Test programme
  - Spice test
    - Instrumental measurements
    - Taste-profile analysis
    - Hygienic test
  - Packaging test
    - Water vapour, O_2, CO_2 permeability of packaging material (foil)
    - Barrier behaviour of closure
    - Light transparency
    - Mechanical test of foil
    - Sealing test of sachets
- Evaiution of measurements (for spices and packaging)
  - Data analysis
  - Selection of critical property(ies) of spices
  - Curve fitting (of quality changing)
  - Interaction between the packed spices and packaging
  - Shelf-life calculation of different packed spices
  - Error of shelf-life estimation
- Conclusion

3. Lecture for shelf-life estimation of food and foodstuffs

According to the request of the National Project Co-ordinator the topic is an explanation of the basic theory of food deterioration and shelf-life estimation for fresh and processed food. It takes 8 weeks and once a week (wednesday), 2 hours.

The main chapters are as they follow:

- Characterization of food
- Relatively stable and changing attributes of food
- Factors influence the quality
- Mechanism and kinetic of quality changing
- Possibilities to inhibit or reduce the rate of reactions
- Shelf-life estimation of food
- Shelf-life and packaging
- Possibilities of shelf-life extension

4. Recommendations for further activities

Bangkok, 11 July 1991.

I. Varsanyi

UNIDO Consultant

ANNEX 3

WORK PLAN FOR SHELF-LIFE DETERMINATION OF RAMBUTAN

Fruit selection

The colour of Rambutan fruit and the ripeness has a tight correlation. Since the colour of fruits is a quality attribute therefore we selected them according their shade of colour and we formed 12 grades, from light yellow to dark red. The 12 grades of colour gave the 6 groups of Rambutan quality (1-2, 3-4, 5-6, 7-8, 9-10 and 11-12) and we made photos to fix the colour grades for reference. The series of pictures is one of the tools to follow the quality changing of stored fruits for shelf-life estimation.

After that we selected 3 groups from the 6 for storage, according to the experiences of fruit dealers, which are the follows:

2nd group (3rd and 4th colour grade),
3rd group (5th and 6th colour grade),
4th group (7th and 8th colour grade).

Two other groups were selected as "following references ", namely

1st group (1st and 2nd colour grade),
5th group (9th and 10th colour grade).

Storage conditions

Investigating the data of duration, temperature, relative humidity and light of harvesting, sorting and grading, transportation to packaging house, transportation to foreign market (Fig. 1) we stated the storage conditions as they are following:

Temperature : 30°C, 22°C, 14°C (it also is reference).
Relative humidity : 85% (constant)
Light : without light, in dark (constant)
Storage time : 18 days (shelf-life is 7 days on ambient temperature)

Sampling programme

It would be investigated 3 units per variations per temperature as paralleles in every second day. The basic population is 9 (days) x 9 (3 temperatures x 3 packages) = 81 units per variations (package variations and quality attributes). The packages would be tested on the 9th and 18th day.

Packaging design

Retail packaging

The unit requested in 1 kg, which contains approximately 30 pieces of fruits. The form of packages are the following:

- Present form (paper-carton box, the fruits are in one layer),
- Present form of box and inside perforated polyethylene foil for fruit wrapping to decrease the losses of transpiration and respiration,
- Paper-carton box for one layer of fruits which would be separated by inserts.

Consumer packaging

The unit requested is for 6 pieces of fruits, they are separated by inserts. The box is pre-cut paper-carton opened on top side, which is 6 cm (H) x 9 cm (L) x 5 cm (W). Two variations of packages will be investigated:

- The paper box is overwrapped on six sides with stretch PVC foil,
- The paper box is wrapped on four sides (two sides of ends are unwrapped) with the same quality of stretch PVC foil.

Test programme

According to sampling programme the fruits would be tested - as the treated so the untreated with same method - on every second day. The packages would be tested on the half-time (9th day) and on the end of investigation (18th day), regarding to the relevant standards.

Fruits test (min. three parallel per aspect)

Instrumental test

- Colour test by etalon
- Weight loss
- Water content of spinterns + peel
- Carbohydrate content (total) of aril
- Vitamin C content of aril

Sensory test (score system is 4 x 5 points = 20 max.)
- Colour (1-5)
- Firmness of spinterns (1-5)
- Skin appearance (1-5)
- Impression (1-5)

Total score (4-20)

Hygienic state and disease symptoms
- Black spots (number on the surface and the total size if it is necessary)
- Other fungal pathogens (identification and characterization)
- Qualification of hygenic state (good, acceptable, unacceptable)

Packaging test (control sample is the unused box)

Retail packages

- Without packed goods
  = Compression on 2 sides
  = Free fall
  = Quality of adhesived sides or overlapped parts

- With packed goods
  = Compression (according to the storage circumstanees)
  = Vibration (according to the stresses of transportation)
  = Free fall (according to the handling of packages)

After the tests it is necessary to qualify the packed fruits by sensoric way.

The Table 1 gives synoptic of tests.

Consumer packages (control sample is the unused box)
- The procedure of tests would be done in retail package form, in same as it is datailed of "Retail packages",
- Permeability test of wrapping foil includes the test of water vapour, CO_2 and O_2 permeability,

Test of wrapping (tightness and closure effects)

Evaluation of measurements

Data analysis

- Calculation of mean values, standard deviations of parallel measurements.

- Calculation (control) of homogeneity of variances according to treatments (e.g. packaging, temperature, storage time) or to attributes investigated (e.g. changing of vitamin C content, cell count number, sensory properties). It is the Bartlett type χ^2-test.

  = If the variances are homogeneous we may calculate the effect of certain treatment (e.g. packaging, temperature, storage time) by one-way analysis of variances or the combined effects (e.g. packaging and temperature, packaging and storage time, temperature and packaging) by two-ways analysis of variances. It is the F-test, which would be applied in special cases by Student type t-test or by Streuli type t-test.

  = If the variances are not homogeneous we have to make control calculations to determine the standing out values by Dixon type r-criteria.

Selection of critical property(ies)

Regarding the results of various analysis we can select the most rapidly changing property(ies) of packed good or of packaging material in the function of storage time.

Curve fitting

According to the parameters of treatments (e.g. storage temperature is 30°C and 22°C and 14°C) we form homogeneous population and in the function of storage time we search the curves which approach most the significant parameters change in the function of storage time. The curves would be linear : $y = a - bx$

quadrat : $y = a - bx^2$

exponential : $y = ae^{-bx}$

sigmoid : $y = a - \frac{a}{1 + e^{bx}}$

hyperbola : $y = ax^{-b}$

where

y = value of "critical" property changed
a = original (started) score value of quality
b = quality changing rate constant
x = storage time

Comparison of curves

We may suppose the t-distribution of regression coefficients and the degree of freedom in (2n-4) where n is the number of measurements and then we can compare the steepness of curves. The result of calculation gives the most rapidly changing parameter (property) of stored food or packaging material or package tested in the function of storage time. The most rapidly changing parameter gives the so-called "critical" property of material investigated.

Shelf-life calculation

According to the national or international standards we have to know the threshold value of most rapidly changing attribute of our food or packaging material. On the base of threshold value of critical property we can calculate the shelf-life of material investigated by interpolation of quality changing curve and equation, respectively. The result of interpolation gives the "critical" time of storage which means the shelf-life of investigated good.

Curve fitting accuracy

We will receive the interval confidency of curve - the curve gives the base of shelf-life calculation - if we will calculate the standard error of expected value. For shelf-life calculation it is the best approach to achieve the smallest standard error of expected value. The calculated standard error gives the accuracy of shelf-life determined.

Conclusion

The shelf-life of produce or product investigated is valid just in the given parameters of storage circumstances, for example: temperature, relative humidity, radiation of light, packaging material, container form and colour. Extrapolation is possible in special cases for example: other permeability value, thickness, active surface and container form.

Fig. 1. The time vs. temperature chart of rambutan from harvesting till marketing

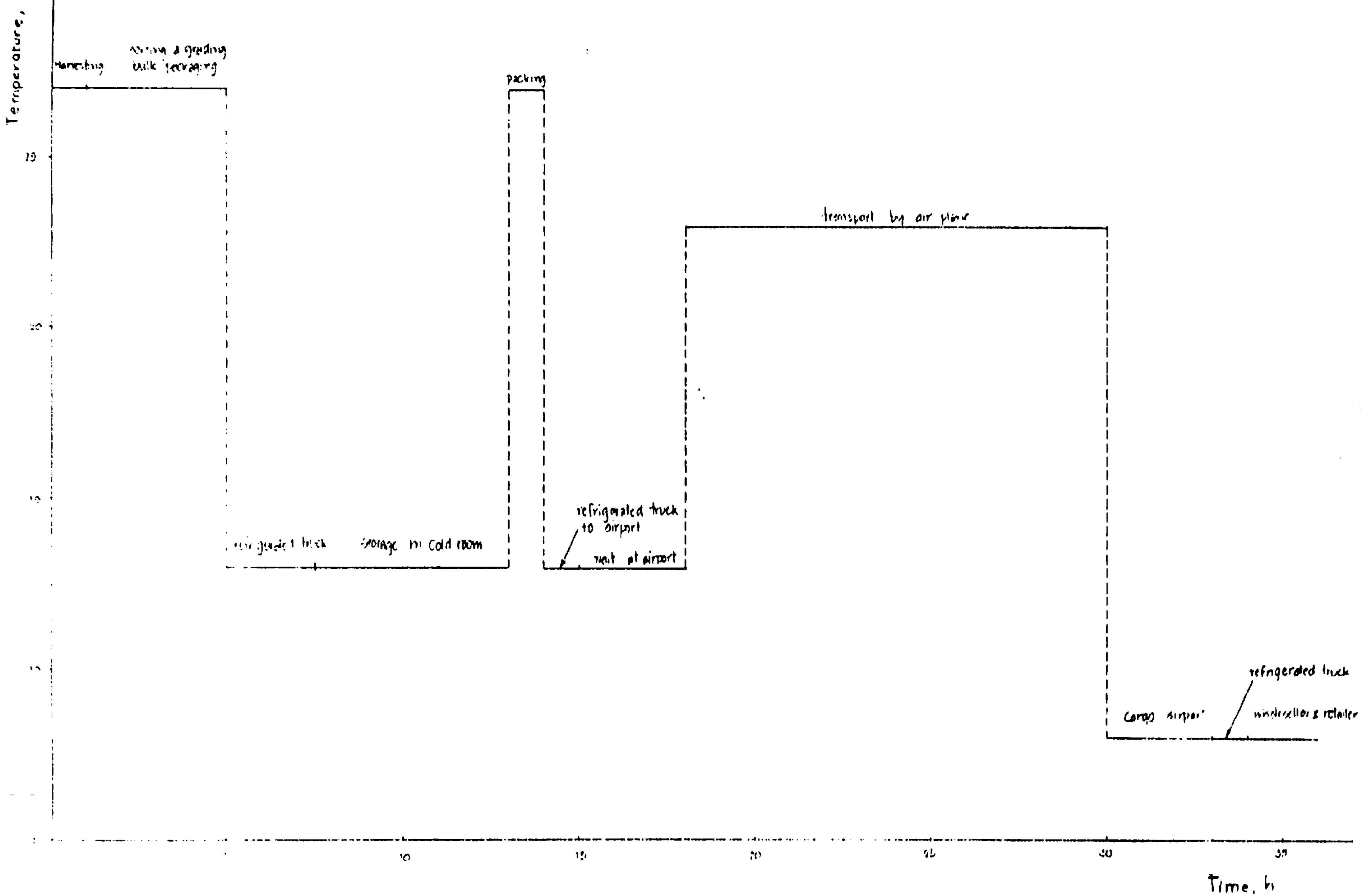

Table 1. Mechanical tests for retail packages

Tests	Prior conditioning			Tests	Number of packagings tested	
	Wood	Paperboard	Plastics materials		Approval	Control
Compression				$F = 1.5\left[\frac{H}{h} - 1\right]P$	5, separately	5, separately
Vibration	(Not applicable)	48 hours at 90 ± 2 % (humidity) and 20 ° ± 2 °C (temperature)	Approval: 48 hours at 40 ° ± 2 °C Control: 48 hours at 40° ± 2 °C	Additional load: $m = (\frac{220}{h} - 3)P$ Amplitude: 9 mm horizontally 9 mm vertically Frequency: 4 hertz Duration: 2 × 10 mm	3 groups of 3	1 group of 3
Free fall				$H = 70 - P$ 2 falls per packaging[1]	5 packagings[2]	2 packagings
					Total 19 packagings[3]	Total 10 packagings

1 For the free fall test for the approval of packagings including plastics materials, an additional series of tests shall be carried out with 5 packagings conditioned for 48 h at − 10° ±

2 10 for packagings including plastics materials.

3 24 for packagings including plastics materials

MAIN ASPECTS OF RAMBUTAN PACKAGING

Physical properties

Weight

Table 3.3 Weight (gm.) of fruit, rind, pulp and seed of rambutans at marketable stage

Variety	Fruit	Rind	Pulp	Seed
'Binjai'	27.3	11.2	11.7	2.51
'Lebakbulus'	26.9	12.7	11.2	2.12
'Maharlika'	24.1	—	—	—
R3	27.9	—	12.9	—
R134	26.9	—	12.3	—
R162	31.0	—	14.6	—
'Rapiah'	20.1	8.7	9.5	1.58
'Seechompoo'	31.1	14.5	13.0	1.80
'Seematjan'	41.3	—	—	—
'Seenjonja'	17.1	—	—	—

Source: Kosiyachinda, Laksmi, Lam and Mendoza; unpublished data.

Colour

Light can affect colour development of the fruit since the anthocyanins which give rise to the red colour in the rambutan skin are sensitive to light intensity. This is usually seen on fruit found in the inside part of the tree which are less brightly coloured when ripe than those on the outer branches which are in direct contact with sunlight. There are no reports, however, on which wavelengths of light affect colouration of rambutan fruit.

Table 3.2 Harvesting criteria of some ASEAN rambutan varieties based on fruit colour

Country/Variety	COLOUR		
	Fruit	Skin	Spinterns
Indonesia			
'Binjai'	reddish orange	red	red with yellow tip
'Lebakbulus'	reddish orange	reddish orange	red with yellow tip
'Rapiah'	reddish orange	greenish yellow	red with yellow tip
Malaysia			
R3 ('Gula Batu')	red	red	red with green tip
R134	red	red	red with yellow green tip
R156('Muar Gading')	yellow	yellow	yellow with pink base
R162 ('Daun Hijau')	yellowish red	yellowish red	red with yellow green tip
Philippines			
'Maharlika'	yellowish red	pink, tinge of yellow	pinkish red, yellowish green tip
'Seematjan'	pinkish yellow	yellowish green	pinkish yellow, greenish yellow tip
'Seenjonja'	pinkish yellow	reddish orange	reddish orange
Singapore			
'Jitlee'	reddish orange	reddish orange	reddish orange
Thailand			
'Rongrien'	reddish orange	reddish orange	reddish orange
'Seechompoo'	pink	pink	yellowish pink

Chemical Characteristics

The taste of the rambutan fruit is a blend of sugars and acids. Determination of total soluble solids (TSS) is a measure of both sugars and acids and can be easily carried out with a hand refractometer. Most fruit at maturity have TSS in the range of 17 to 21% (Table 3.4). Table 3.4 also shows that the titratable acids (TA) expressed as anhydrous citric acid is 0.07 to 0.55%, and the pH is around 4 to 5.

Table 3.4 Chemical composition of some varieties of mature rambutan

Variety	TSS (%)	TA (%)	pH
'Binjai'	18.0	0.19	4.33
'Jitlee'	19.2	0.27	4.6
'Lebakbulus'	17.0	0.40	4.25
'Maharlika'	20.4	0.42	—
R3	19.7	0.23	—
R134	21.1	—	—
R162	20.1	—	—
'Rapiah'	17.2	0.07	5.33
'Rongrien'	20.0	0.30	4.26
'Seechompoo'	19.0	0.18	4.50
'Seematjan'	17.9	0.35	—
'Seenjonja'	19.5	0.55	—

Source: Kosiyachinda, Laksmi, Lam, Mendoza and Yong, unpublished data

The vitamin and mineral composition of the aril is shown in Table 4.3.

Table 4.3 Composition of rambutan per 100g edible portion

	(g)			(mg)	
Water	82.1	c	Niacin	0.5	c
Protein	0.9	c	Carotene	0	c
Fat	0.3	c	Phosphorus	0	c
Ash	0.3	c	Calcium	15	c
Glucose	2.8	b	Iron	(0.1	b
Fructose	3.0	b		(2.5	a
Sucrose	9.9	b	Vitamin C	70	c
Starch	0	b	Thiamine	0.01	c
Dietary fibre	2.8	b	Riboflavin	0.07	c
Malic acid	0.05	b	Potassium	140	c
Citric acid	0.31	b	Sodium	2	c
Energy	297 kJ	b	Magnesium	10	c

Sources: a: Tee (1982)
b: Wills, Lim and Greenfield (1986)
c: Mean of data from a and b

Chemical components changing during storage

Mendoza *et al.* (1972) found that the TSS and TA in 'Seematjan' rambutan harvested at the yellow and red maturity stages rose slightly with increasing length of storage at 21°C while starch content decreased with storage (Table 4.4). Less mature (one-third ripe) fruit showed higher TA and starch levels but lower TSS than fully ripe fruit. In another experiment on the same cultivar where fruit were stored at 26-32°C for six days the aril showed no significant change in TSS, which averaged 24° Brix (Agravante and Lizada, unpublished data). Similarly, the TA and pH did not change significantly over the six-day period, averaging 5.7 meq/100g and 4.2, respectively. This observation and the fact that the aril shows only a slight decrease in moisture loss are consistent with the observation that the aril remains acceptable even when the peel shows severe desiccation and deterioration in visual quality.

Table 4.4 Chemical changes during storage of 'Seematjan' rambutan at 21°C

Maturity	Days in Storage	Titratable Acidity (%)	Total Soluble Solids (%)	Starch (%)
⅓ ripe (Yellow)	0	0.27	14.0	5.8
	4	0.30	15.0	5.2
	8	0.32	15.5	3.0
Fully ripe (Red)	0	0.24	14.5	3.4
	4	0.29	15.5	2.6
	8	0.30	16.5	2.0

Source: Mendoza *et al.* (1972)

The TSS of 'Seechompoo' and 'Rongrien' cultivars harvested 19 and 22 days after colour break averaged 18.7% and 19.5%, respectively, and the values increased by 1.5% and 0.1%, respectively, after 9 days of storage at 10°C (Somboon, 1984). Somboon also showed that 'Seechompoo' and 'Rongrien' fruit of 19 to 22 days and 16 to 22 days after colour break respectively had an acceptable good taste when stored either at 5°, 10° or 15°C for nine days. Fruit harvested at other maturity stages had inferior taste. Taste changes in all fruit were minimal when stored at 10°C.

Chemical composition and colour

In the study by Wanichkul and Kosiyachinda (1982), the TSS of 'Seechompoo' on the 10th day after rind colour break (13 to 14 weeks after fruit set) is about 16%. This increases to about 21% on the 31st day (16 to 17 weeks after fruit set, which is the stage of full maturity) (Figure 3.13). On the other hand, the acid content of the extractable juice decreases almost 40% from the 10th day to the 22nd day, with the most rapid decrease occurring from the 10th to the 16th day. The acid content is 0.26% on the 10th day and 0.16% at the over-mature stage.

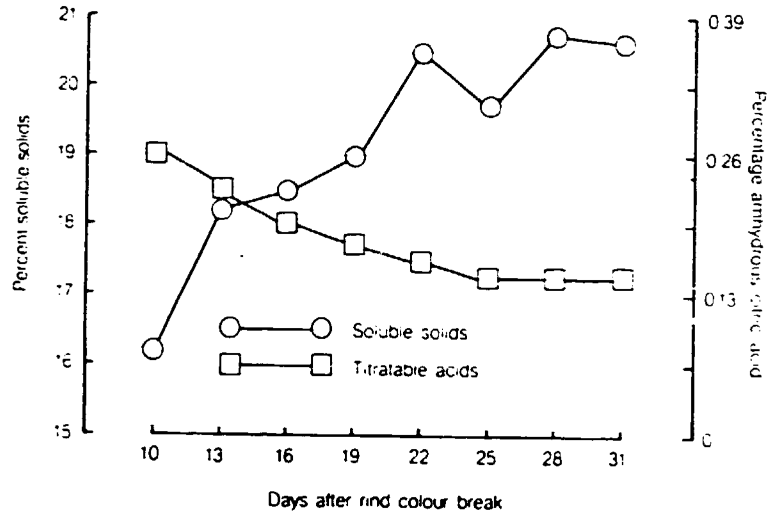

Figure 3.13 Soluble solids and acid content of 'Seechompoo' fruit harvested at various times
Source: Wanichkul and Kosiyachinda (1982)

For 'Seechompoo', rind and spintern colour changes have been found to be related to changes in TSS and TA content of the pulp. It is observed that 19 days from the rind colour break (15 weeks from fruit set) the fruit is suitable for harvest, having 19% soluble solids and 0.17% anhydrous citric acid (Figure 3.14). 'Rongrien' rambutan should be harvested on the 16th week when the fruit has 22% TSS and 0.16% TA, R3 on the 16th to 17th week, and R156 on the 15th to 18th week after fruit set. If they are over-mature, pest problems may occur and storage and marketable life is shortened. Farmers, however, will obtain a good yield if fruit are picked on or after 19 days of rind colour break. Fruit picked 10 days after rind colour break may be marketed as an early-season crop, but their quality will not be very high.

Lam (1983) followed the chemical composition of R3 and R156 rambutan at different stages of maturity. He found that TSS, sugars and starch increased during maturation, but the level of TA decreased (Table 3.5).

Table 3.5 Chemical composition of R3 and R156 rambutan at different maturity stages

Variety	Weeks After Fruit Set	Fruit colour	TSS (%)	TA (%)	Sugar (%)	Starch (%)
R3	15	Half red	17.8	0.31	7.9	1.7
	16	Full red	19.7	0.24	8.9	2.3
	17	Dark red	22.0	0.23	16.0	3.0
R156	13	Full green	10.3	1.06	5.2	1.7
	14	Slightly yellow	12.3	0.74	7.0	2.6
	15	Full yellow	16.0	0.26	10.4	2.5
	16	Full yellow	17.0	0.27	6.0	1.6
	17	Full yellow with purple tinge	17.0	0.14	7.4	2.7
	18	Full yellow with more purple	20.0	0.15	13.8	2.9

Source. Lam (1983)

Weight and colour changes during storage

Deterioration in harvested rambutan is characterized by the browning of the peel, which starts at the top of the spintern and progresses on to its base. Browning is usually associated with desiccation and is aggravated by mechanical injury. Extreme desiccation leads to the browning of the entire peel, although the aril might still be acceptable.

Mendoza *et al.* (1972) found a high rate of weight loss in 'Seematjan' fruit held at 25°C (Table 4.1). Likewise, Wanichkul (1980) observed that 'Seechompoo' fruit of eight maturity stages after colour break lost 15% in weight in the first two days after harvest at ambient temperatures and after a further three days the total weight loss was 25%. Prabawati and Lakmi (1982) found that 'Binjai' and 'Lebakbulus' rambutan lost 22% and 19% of their weight after eight days and six days of storage, respectively, at ambient conditions.

Table 4.1 Weight loss at 25°C of 'Seematjan' at the initial and full stages of ripening

Stage of ripeness	Weight loss (%)			
	8	16	24	32 hours
ripe (Yellow)	2.8	6.6	17.8	20.2
fully ripe (Red)	3.8	7.2	17.6	20.0

Source Mendoza *et al.* (1972)

Agravante and Lizada (unpublished data) observed that when 'Seematjan' fruit are kept at room temperature (26-32°C) deterioration of visual quality sets in several days after harvest. Figure 4.1A illustrates the progress of deterioration in the visual quality of the 'Seematjan' fruit. The progressive decline in quality can be attributed primarily to the browning of the spintern. Although the latter was evident at harvest, it was confined to the tips.

No significant increase in browning was observed in the fruit one day after harvest, although they exhibited a cumulative weight loss of 9% (Figure 4.1A). Beyond this point, however, browning progressively increased up to the 6th day after harvest when weight loss exceeded 50%. The spinterns were completely brown and the rest of the peel started to show discolouration near the base of the spinterns. That browning is highly correlated with weight loss is illustrated in Figure 4.1B. This relationship between browning and weight loss is in agreement with the results of the earlier work of Mendoza and Pantastico (1976).

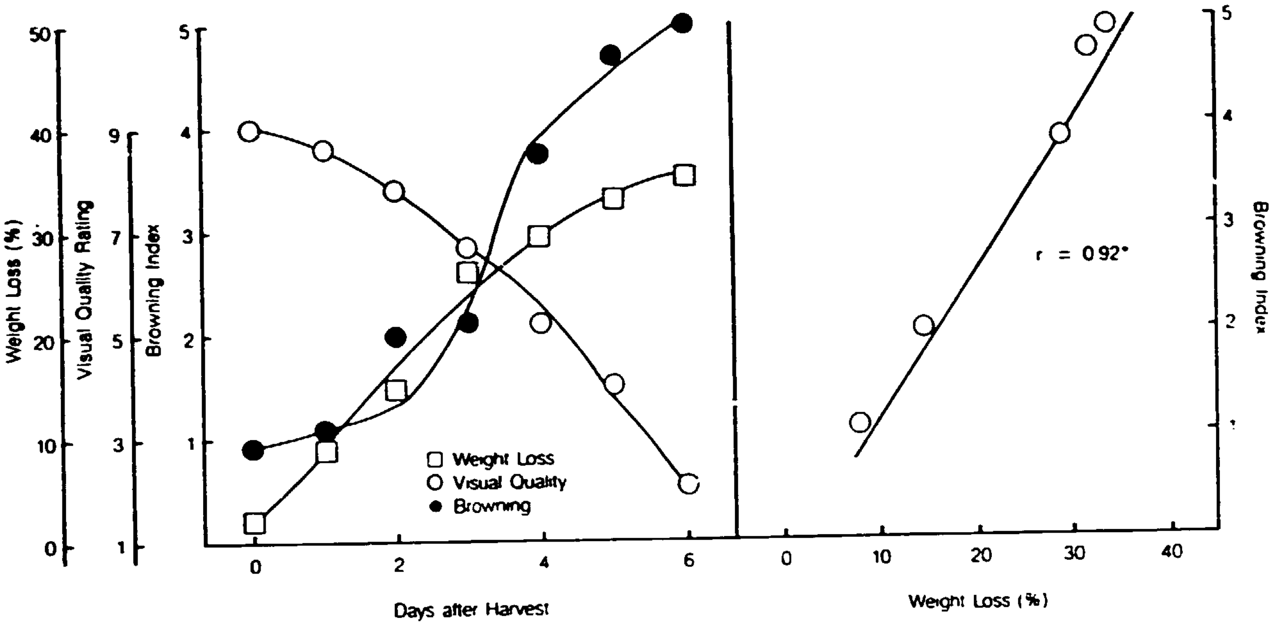

Figure 4.1A and B Progressive deterioration in the quality of the 'Seematjan' fruit
(A) Weight loss, visual deterioration and browning in 'Seematjan' fruit. Visual quality ratings 9, 8 = excellent, 7, 6 = good defects slight., 5, 4 = fair, defects moderate, 3 = limit of marketability, defects serious, 2,1 = not marketable. Browning index 1 = up to ¼ of spintern brown, 2 = ¼ to ½ of spintern brown, 3 = ½ to ¾ of spintern brown, 4 = more than ¾ of spintern brown, 5 = entire spintern brown
(B) Relationship between weight loss and browning
Source: Agravante and Luzada (unpublished data)

In another study (Agravante, 1982), it was observed that weight loss in rambutan can be attributed mainly to the loss of moisture in the peel, specifically through the spinterns (Table 4.2). The high surface area to volume ratio in the spintern, as a consequence of its shape and size, partly accounts for its high propensity to moisture loss. Furthermore, the lenticels present in the spintern can serve as avenues for moisture loss (Pantastico *et al.*, 1975). In contrast, the aril shows little weight loss even when the peel exhibits moderate desiccation (Table 4.2).

Table 4.2 Changes in moisture content over a 72-hour period

Time of harvest (h)	Moisture Content (%)			
	Spintern	Peel	Aril	Seed
0	76.2 a	81.4 a	81.2 a	44.7 a
6	74.2 b	80.8 ab	81.0 a	44.5 a
12	73.2 c	79.6 bc	81.0 a	45.0 a
24	73.2 c	78.6 cd	80.4 ab	45.2 a
48	71.3 d	77.7 d	80.2 ab	44.1 a
72	68.1 e	74.7 e	79.6 b	46.5 a

Peel moisture content was determined after excision of the spinterns at the base

Means with different letters within the same column are significantly different, with the Duncan Multiple Range Test at 5%

Source: Agravante (1982)

Enzyme activities and maturity

Normah *et al.* (1983) show that an increase in activity of both pectin methylesterase (PME) and polygalacturonase (PG) occurs with fruit maturity in R156. This increase is more pronounced after the 13th week, suggesting an association with the onset of ripening as shown by the change in skin colour from dark green to slightly yellow (Figure 3.11). Soluble pectin and protein contents show changes similar to pectin enzyme activity with the level being relatively constant until the 13th week, after which there is a gradual increase until maturity. An increase in pectin enzyme activity at maturity has been demonstrated in tomato, cherry, orange and lemon (Forgarty and Ward, 1972), and since most fruits contain PME and PG, it is likely that changes in these activities in rambutan are responsible for pectin solubilization and that such changes are involved in rambutan ripening.

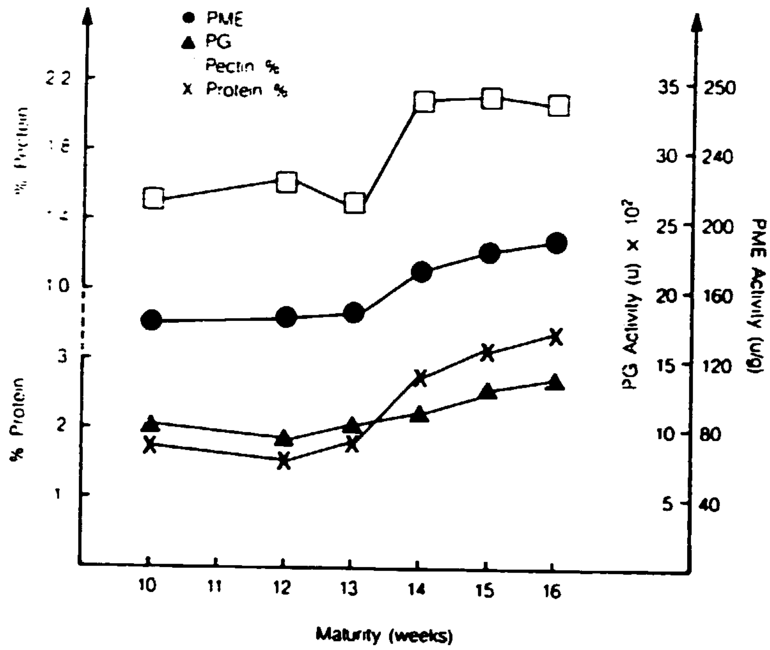

Figure 3.11 Enzyme activities and changes in protein and pectin contents in R156 rambutan
Source Normah *et al* (1983)

Harvested fruit respiration

Mendoza *et al.* (1972) found that rambutan harvested at various stages of maturity showed high respiratory activity immediately after harvest with immature fruit having a higher respiration rate than more mature fruit. All fruit, however, showed a decrease in respiration with time after harvest. They concluded that rambutan is a non-climacteric fruit.

In contrast, 'Rongrien' and 'Seechompoo' fruit exhibited a decrease in respiration rate for the first day followed by an increase to a maximum of about 55 ml CO_2/kg/h at 25°C (Figure 4.2; Kosiyachinda, unpublished). This increase in respiration coincided with the desiccation of the peel and spinterns. Ethylene evolution in these fruit was not detectable immediately after harvest, but was measured at 0.25 and 0.49 μl/kg/h one day after harvest (Figure 4.2). The rates reached maximum values of 2.6 and 2.0 μl/kg/h for 'Rongrien' and 'Seechompoo', respectively.

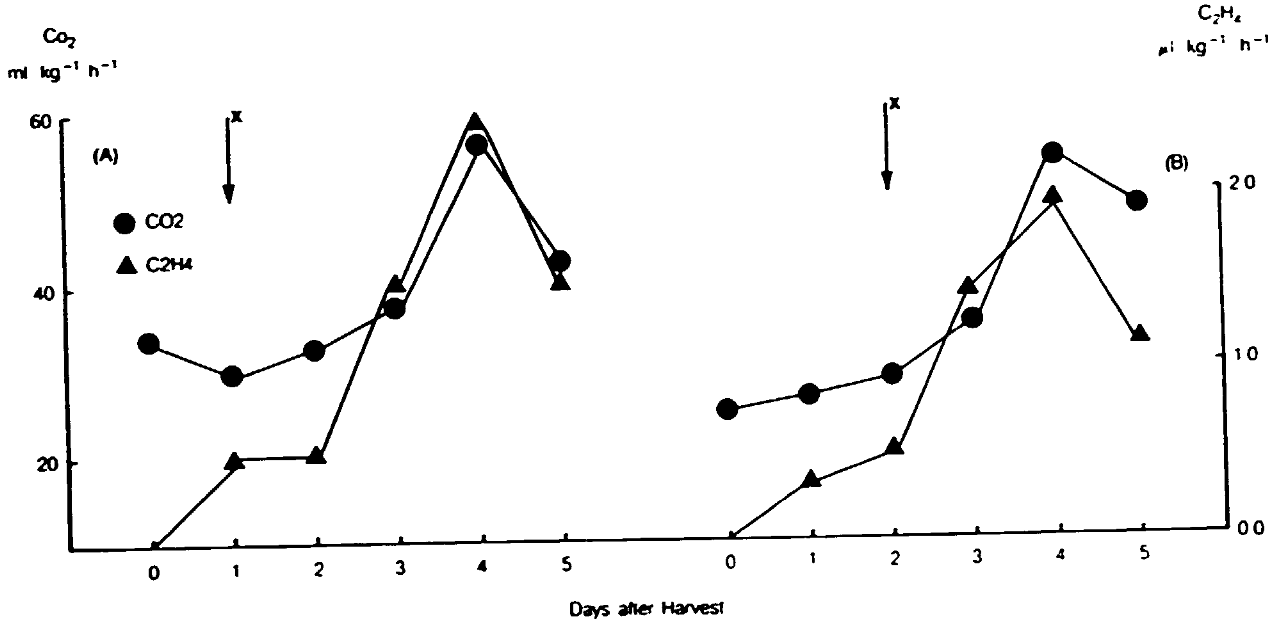

Figure 4.2 Respiration rate and ethylene evolution in 'Rongrien' (A) and 'Seechompoo' (B) fruit at 16 to 22 days after colour break at 25°C. 'X' began to exhibit desiccation of peel and spinterns.
Source: Kosiyachinda (unpublished data)

Similarly, 'Seematjan' fruits showed significant increase in both respiration and ethylene production rates during storage at 26-32°C. Figure 4.3 illustrates the pattern of respiration production in fruit harvested at the full stage of ripeness.

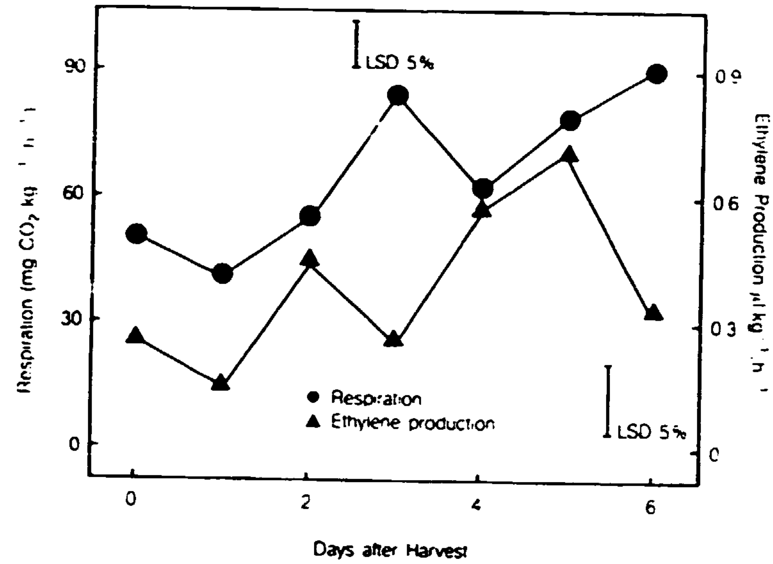

Figure 4.3 Respiration and ethylene production in harvested 'Seematjan' fruit
Source: Agravante and Lizada (unpublished data)

These fruit also produce ethylene at moderate rates ranging from 0.14 to 0.72 μl/kg/h, such that the levels of this gas within the fruit ranged from 0.14 to 0.80 μl/l.

Although rambutan produces ethylene and exhibits an increase in respiration after harvest, this is not associated with ripening but with deterioration. A similar observation has been made in the case of lanzones where the increased respiration occurs concomitantly with weight loss and deterioration (Agillon *et al.*, 1984). Ethylene production in rambutan can be considered as stress ethylene production resulting from moisture loss (Yang, 1980).

Respiration and colour changing

These fruit exhibited a significant increase in respiration three days after harvest when slightly more than 25% of the spintern surface showed browning. This increased respiration rate was reflected in the increased levels of CO_2 within the fruit four days after harvest when the average browning index was 4 (75% of spintern surface showing discolouration; Figure 4.4).

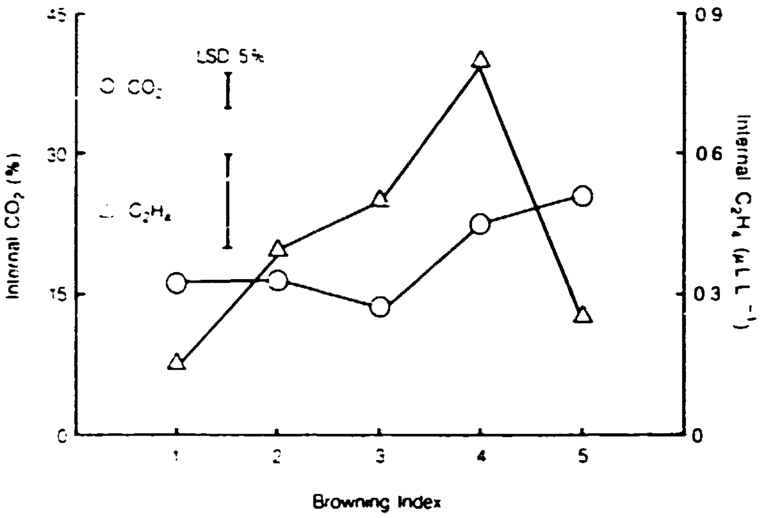

Figure 4.4 Browning index in 'Seematjan' fruit and internal levels of carbon dioxide and ethylene in harvested 'Seematjan' fruit (gases were extracted under vacuum from fruit submerged in water)
Source: Agravante and Lizada (unpublished data)

Temperature and packaging (polyethylene bag) effects on respiration, weight and colour

Weight loss of rambutan is affected by storage temperature. Mendoza *et al.* (1972), in a study of the 'Maharlika' fruit, found that weight loss after six days at 31°C was about 46% while at 7°C it was about 28% with intermediate weight loss (Table 4.5). Table 4.5 also shows striking reductions in weight loss achieved by storing the fruit in perforated polyethylene bags, with the loss, at 31°C, being about 4%. Sealing the bags further reduced weight loss, with values of less than 1% being obtained at all temperatures. The use of polyethylene bags alone thus more effectively reduces transpiration weight loss than refrigeration.

Table 4.5 Weight loss after six days' storage of 'Maharlika' rambutan at different temperatures, exposed fruit and in polyethylene bags

Temperature/Treatment	% Weight Loss
31°C Open	46.5
Perforated bags	3.8
Sealed bags (3.3% CO_2 — 7.9% O_2)	0.6
27°C Open	44.8
Perforated bags	3.5
Sealed bags (3% CO_2 — 8.2% O_2)	0.5
15°C Open	33.7
Perforated bags	3.2
Sealed bags (2.8% CO_2 — 8.6% O_2)	0.5
10°C Open	29.1
Perforated bags	2.8
Sealed bags (2.4% CO_2 — 9.0% O_2)	0.4
7 °C Open	28.2
Perforated bags	2.5
Sealed bags (2.2% CO_2 — 9.3% O_2)	0.4

Source: Mendoza *et al.* (1972)

The carbon dioxide and oxygen levels generated inside the sealed bags would appear to be sufficient to produce some retardation of senescence, but the sealed bags also accelerated rot development, particularly at the higher temperatures. This limits the usefulness of modified atmosphere storage at high temperatures. On the other hand, storing fruit at 7°C caused chilling injury of the peel and spinterns, although eating quality was still acceptable (Somboon, 1984; Mendoza *et al.*, 1972). Initial symptoms of chilling injury are shown by the darkening of the spinterns and skin. Lam and Ng (1982) found that rambutan could be stored up to five weeks at 5°C without the aril being attacked by diseases, although the fruit shrunk in size and the skin appeared dry.

Mendoza *et al.* (1972) also subjected exposed fruit and fruit stored in polyethylene bags to temperatures of 35° and 40°C for 12 and 24 hours to simulate storage in sunlight (Table 4.6). They found that drying of the spinterns was least but weight loss was highest in exposed fruit. Desiccation was least but drying of spinterns was highest in fruit stored in sealed bags. It appears that very high temperature and relative humidity cause some damage to the spintern, that in turn results in accelerated water loss.

Table 4.6 Effect of high temperatures on transpiration and spintern drying of rambutan

Treatments	Holding Period (Hour)	Weight Loss (%)		Drying of Spinterns (%)	
		35°C	40°C	35°C	40°C
A Sealed	12	0.67	0.91	31.4	64.0
	24	1.29	2.01	48.6	
B Perforated	12	0.85	1.09	26.6	34.0
	24	2.28	2.89	43.5	86.0
C Exposed	12	3.56	4.83	12.8	30.2
	24	10.21	10.92	32.3	50.0

Source: Mendoza *et al.* (1972)

Other researchers have subsequently examined the storage of rambutan in polyethylene bags. Prabawati and Laksmi (1983) studied 'Binjai' and 'Lebakbulus' rambutan stored at ambient temperature and kept in sealed polyethylene bags and in bags perforated with 8 or 64 pin holes. In all the packaging treatments, the spinterns lost the most weight followed by the skin and then the aril. Packaging in perforated bags also resulted in less off-flavoured fruit than when fruit were stored without packaging.

Somboon (1984) harvested 'Seechompoo' and 'Rongrien' rambutan at six colour stages, from 13 to 28 days after colour break at three-day intervals, and stored them in sealed polyethylene bags at 5°, 10° and 15°C. Weight loss was 0.05% after three days at all temperatures. On the 9th day, the weight loss of 'Seechompoo' at 5°C was 0.75% while at 15°C it was 1.74%.

Lam and Ng (1982) packed bunched R3 and R156 rambutan in control, perforated and sealed polyethylene bags and stored them at different temperatures. All fruit tended to abscise on the 4th or 5th day of storage at 20°C. Fruit stored at 10°C and 5°C had better storage life than at ambient and 20°C. At 10°C, they lost their original skin colour and freshness after one week in perforated and sealed bags. R3 and R156 fruit showed dark red and brown-yellow areas on the skin, respectively, at 5°C, but the aril was good and edible after three weeks of storage. Weight loss was greatest at ambient conditions (24-33°C), reaching 45% after nine days of storage. Fruit stored in sealed bags showed negligible weight loss (less than 1.5%) during storage. The percentage of carbon dioxide in sealed bags varied from 1 to 8%, oxygen from 5 to 19%, and ethylene from 0.05 to 1.3 μl/l.

Lee and Leong (1982) stored 'Jitlee' rambutan in sealed polyethylene bags (0.023 mm and 0.056 mm thick) and in polyethylene bags with two holes of 6 mm diameter. They found that the fruit in all three polyethylene bag treatments were still fresh after seven days storage at 10°C, whereas control fruit showed signs of dehydration within one day. After an additional seven days, fruit in the 0.023 mm sealed bag showed some browning, whereas fruit in the perforated bag had already turned brown. In contrast, fruit in the 0.056 mm sealed bag were still fresh with only very slight browning

Moisture loss in the three polyethylene bag treatments was low, ranging from 0 to 0.4%. The carbon dioxide level in the 0.056 mm sealed bag ranged from 7.5% to 9.2% and was fairly constant at seven and 14 days after storage. It appears that this level of carbon dioxide is optimal in retarding the browning process in rambutan.

Thus, it appears that the best storage temperature is 10°C at which the fruit remains marketable for 12 days inside sealed polyethylene bags and 10 days in perforated bags.

Hygienic aspects

Disease symptoms

Rambutan fruit inoculated with *Botryodiplodia theobromae* show rapid infection as a dark brown lesion which extends over the whole fruit within four to five days. Some dark-coloured hyphal masses may develop on heavily rotted tissues. Infection of *B. theobromae* is mainly through injuries or wounded tissues. The cut stem end is a major entry point for this disease and results in stem end rot of the fruit.

Fruit inoculated with *Gliocephalotrichum bulbilium* show initial symptoms of light-brown water-soaked areas in the rind and pulp. As the spots enlarge they become dark-brown. Greyish brown mycelia can be seen in infected areas under moist conditions. Symptom development is less vigorous than *B. theobromae* and the fruit is considered spoilt in eight days. Heavily infected tissues usually result in yellowish fungal mycelia with sporulation on the fruit. Eventually, the fruit become black, mummified and dry.

Fruit inoculated with *Colletotrichum* sp. show similar symptoms to those caused by *G. bulbilium*. However, symptom development is less extended and no aerial growth of mycelia is observed on heavily infected fruit.

A survey of these three fungal pathogens was carried out in 1984 on rambutans obtained from four market locations in Bangkok. The findings are that 5% of fruit were infected with *Botryodiplodia theobromae*, 30% with *Colletotrichum* sp. and 10% with *Gliocephalotrichum bulbilium*. *B. theobromae* caused further rotting in over-ripe rambutans.

Fungal pathogens

Botryodiplodia theobromae is a rapid-growing fungus which fills a 9 cm diameter petri dish within one to two days. Early growth of the fungus shows white fluffy masses of mycelia which later become dark. Conidial production is rarely observed in Potato Dextrose Agar (PDA).

Gliocephalotrichum bulbilium shows a slower growth rate on PDA and fills up the dish within five days. At this age the hyphal masses in the medium turn to brown-coloured chlamydospores, while the aerial mycelia show white to yellowish clusters of sporulation. Conidia are one-celled, cylindrical, and average 2.5 microns x 7.5 microns (Figure 5.2).

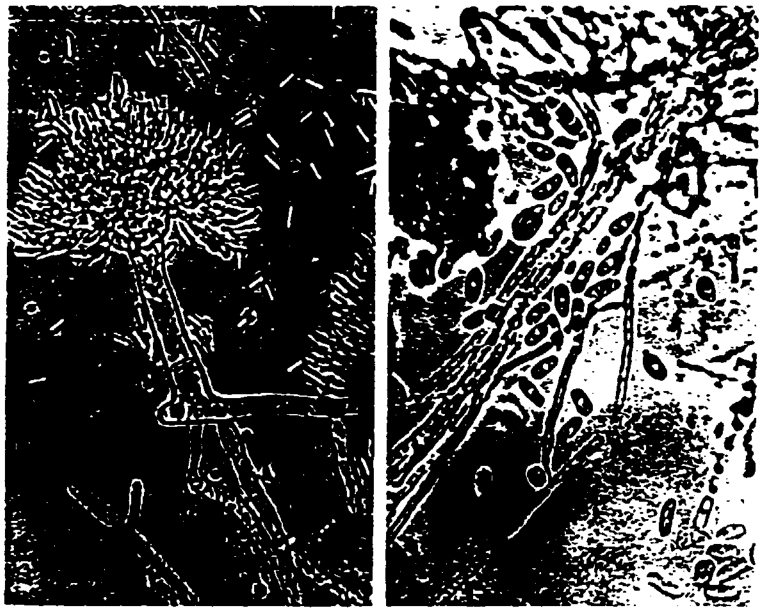

Figure 5.2 Fructification of *Gliocephalotrichum bulbilium* (A) and *Colletotrichum* sp. (B)
Source: Visarathanonth

A wound appears to be necessary for rapid penetration and severe infection by *G. bulbilium*. Pricked and inoculated fruit exhibit extensive necrosis, with the water-soaked and brownish black lesions affecting the fruit within three to four days. Fungal mycelia can be observed growing on the lesions. Unpricked and inoculated fruit, on the other hand, exhibit physiological browning. The affinity of the pathogen for wounds explains why mechanically injured fruit are prone to fruit rot. Infection is also observed to start at the stem end which serves as a natural portal for the entry of the fungal pathogen.

Storage at 10°C delays rot development in *G. bulbilium* inoculated fruit so that four days after inoculation only a slight water-soaking and browning are observed in the pricked areas. These fruit, however, become water-soaked and turn brown a few hours after they are brought to ambient room temperature. Infection progresses rapidly in wounded fruit at 20°C, 30°C, and room temperature (21-29°C). These fruit turn brownish black with mycelia appearing on the injured areas. Inoculated uninjured fruit are discoloured and dry with no apparent infection. Storage at 37°C causes only mild infection in inoculated fruit as the high temperature seems to inhibit the pathogen. However, the fruit turn dark brown and mummified. The incidence and severity of infection increases with the increase in moisture in the inoculated fruit. Lesions are bigger and progresses more rapidly in wet fruit.

Continuous darkness appears to inhibit *G. bulbilium* rot development. Even inoculated, pricked fruit show no signs of infection, although pricked, inoculated lots brown extensively in the dark, and both the uninjured inoculated and uninoculated fruit retain their natural healthy colour and texture in the dark. Inoculated fruit stored under continuous light turn brownish black with mycelia appearing on the injured areas. *Colletotrichum* sp. show a slower rate of growth than *G. bulbilium* and fill the petri dish within nine days. The fungus produces crust like acervulus on culture and liberated many single oval celled conidia, 5.2 microns x 12.7 microns in size (Figure 5.2).

Sites of infection

Two methods of infection by fungal pathogens are considered to cause postharvest rots of rambutan. One method is field infection, where the organism does not produce disease symptoms in the field due to unfavourable growth environment but remains inactive in the fruit tissues as subcuticular hyphae. This kind of infection is termed "latent infection". For rambutan, fungi that may be included in this category are *Gliocephalotrichum bulbilium* and *Colletotrichum* sp. Neither can be eliminated by postharvest treatment alone, and hence, there is need for field fungicidal control. *Colletotrichum* sp., the anthracnose of rambutan, has also been found not to show disease symptoms in the field but develops rots after harvest.

These two fungi can either remain in the host tissues or contaminate the fruit surface. In the latter case, they gain entry through injuries during harvesting, storage and marketing. As soon as favourable conditions and fruit senescence occur they grow rapidly within the fruit. Both *G. bulbilium* and *Colletotrichum* sp. produce masses of spores which are carried by wind and rain splashes and which may escape field spraying and postharvest treatment.

The other method of infection is postharvest infection. *Botryodiplodia theobromae* falls into this category. This kind of fungus is considered a weak pathogen and requires entry through the exposure of the fruit tissues caused by either the cut stem end or injuries. A high incidence of rambutan fruit rots is initiated at the stem end and *B. theobromae* has been constantly isolated from this area of tissue. *B. theobromae* is a fungus that is widely found in the tropics on both living or dead plant materials, including bamboo basket containers used for rambutan. High moisture and high humidity enhance the rapid growth of the fungus, thus facilitating infection of adjacent fruit in the container.

To minimize the development of rots it is suggested that proper management practices such as a programme of field spraying, postharvest fungicide and careful handling practices be introduced.

Careful handling

Care should be taken to ensure that the method of harvesting avoids fruit dropping to the ground. Leaving a one centimetre stem on the fruit will delay infection of the stem end. Care also needs to be taken at all times during packaging and transportation to prevent damage to fruit spinterns or skin.

Transport by road can enhance rot development due to physical damage caused by inadequate packaging and heat build-up from long exposure to high temperatures during transit. Efforts should be made to reduce the size of loads and to lower the fruit temperature during transport.

Since absence of light appears to delay or reduce infection, fruit should be stored in subdued light, in dark-coloured bags, or in a darkened room. It is not known why darkness reduces disease incidence, but it may be related to the development of the pathogen.

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ASPECTS FOR TROPICAL FRUITS' RETAIL AND CONSUMER PACKAGING

Some inserts and cushioning materials to reduce the mechanical effects of transportation including the material handling

- Cell pack
- Flexible partitioning
- Inserts

  H-insert (to improve stacking strenght)

  Z-insert

  U-insert

  Thermoformed polystyrene insert
- Trays

  Mould pulp trays

  Thermoformed PVC trays

  Expanded polystyrene trays
- Paper wool and wood wool
- Loose-fill material
- Plastic foam nets

Tests recommended for retail and transport packaging

SYNOPTIC TABLE OF TESTS

Tests	Prior conditioning			Tests	Number of packagings tested	
	Wood	Paperboard	Plastics materials		Approval	Control
Compression	(Not applicable)	48 hours at 90 ± 2 % (humidity) and 20° ± 2 °C (temperature)	Approval: 48 hours at 40° ± 2 °C Control: 48 hours at 40° ± 2 °C	$F = 1.5\left[\frac{H}{h} - 1\right]P$	5, separately	5, separately
Vibration				Additional load: $m = \left(\frac{220}{h} - 3\right)P$ Amplitude: 9 mm horizontally 9 mm vertically Frequency: 4 hertz Duration: 2 × 10 mm	3 groups of 3	1 group of 3
Free fall				H = 70 - P 2 falls per packaging[1]	5 packagings[2]	2 packagings
					Total 19 packagings[3]	Total 10 packagings

1 For the free fall test for the approval of packagings including plastics materials an additional series of tests shall be carried out with 5 packagings conditioned for 48 h at - 10° ±

2 10 for packagings including plastics materials

3 24 for packagings including plastics materials

ANNEX 6

STANDARDS RECOMMENDED FOR PACKAGING MATERIAL

TESTS OF RAMBUTAN

Sampling	ASTM D 585
Conditioning	ISO 291, ASTM 685
Tensile strength	ASTM D 882
Bursting strength	ASTM D 774-67
Stretching	ASTM D 882
Gas permeability	ASTM D 1434
Water vapour permeability	ASTM E 96, ISO/R 1195

ANNEX 7

WORK PLAN FOR SHELF-LIFE DETERMINATION OF SPICES

Spice selection

Three spices were selected - as models - for shelf-life estimation of different spices regarding to their properties and prices: nut meg (highest value), clove (high value) and white pepper (medium value) in ground (powder) form.

Storage conditions

Investigating the circumstances of marketing we stated the parameters of storage as they follow:

Temperature : ambient (cca 30°C) and 10°C (reference)

Relative humidity : ambient (cca 65%)

Light : without light, in dark (constant)

Storage forme : in sachets separately and in retail packaging (paper box) and in glass bottles, respectively

Storage time : 24 months

Sampling programme

Spices : 3 packages per spices per temperature as paralleles in every 3rd month. The basic population is 8 (month) x 2 (temperature) x 3 (spices) x 3 (parallels) = 144 units per variation of packages and storage forms.

Packages : the packages would be tested at the end of 6th, 12th and 24th month. The references are the unused packages.

Packaging design

Four different packages would be used for 20-30 g spices, two in sachet and two in glass bottle forms. The recommended sizes of sachets would be cca 10 x 15 cm, and the material would be plastic + Alu + plastic foil and plastic + plastic coated or laminated paper regarding to the possibilities of domestic production. A transparent and a brown coloured glass bottle would be used (cca 50 cm^3), the transparent bottle with plastic closure, the brown bottle (reference) with glass cork.

Test programme

According to the sampling programme the spices and the packaging materials would be tested as it follows:

Spice test (min. three parallels per aspect)

Instrumental measurements

- Moisture content (ISO/R 939-1969)
- Extraneous matter content (ISO 927-1980)
- Non-volatile ether extract (ISO 1180-1980)
- Comparative analysis by gas-chromatograph
- Volatile oil extract analysis in UV-range (cca 210 nm)
- Hygienic state investigation (moulds, bacteria)

Sensory test (min. two repeats)

- Taste-profile analysis (dilution would be 50000, 75000, 100000, 125000, 150000) with min. seven panelists (ASTM E 679-79)

Packaging test

- Water vapour and oxigen gas permeability of foils (5 parallels)
- Tensile test (machine and vertical direction, 10-10 parallels)
- Sealing tensile test (vertical and horizontal side, 10-10 parallels)
- Folding test (5, 10 times, and 5 parallels)
- Light transparency
- Barrier behaviour of plastic closure

Evaluation of measurements

The evaluation of measurements would be done according to the standards and the recommended relevant mathematical statistical methods. The main steps are as it follows:

- Data analysis
- Selection of critical property(ies)
- Curve fitting
- Comparison of curves
- Shelf-life calculation
- Curve fitting accuracy

Conclusion

Regarding to the "history" of spices and the packaging, the shelf-life of different ones would be estimated. The estimated value gives the base of market policy.

ANNEX 8

STANDARDS RECOMMENDED FOR SHELF-LIFE ESTIMATION OF PACKED SPICES

Bursting strength of paper	ASTM D 774-67
Sampling	ASTM D 585
Conditioning	ASTM D 685
Spices and condiments - Sampling	ISO 948-1980 (E)
Spices and condiments - Preparation of a ground sample for analysis	ISO 2825-1974 (E)
Spices and condiments - Determination of non-volatile ether extract	ISO 1108-1980 (E)
Spices and condiments - Determination of extraneous matter content	ISO 927-1980 (E)
Spices and condiments - Determination of moisture content	ISO/R 939-1969 (E)
Determination of odor and taste thresholds by a forced-choice ascending concentration series method of limits	ASTM E 679-79
Manual on sensory testing methods	ASTM STP 434, ASTM, 1968
Establishing conditions for laboratory sensory evaluation of foods and beverages	ASTM E 480-84
Test method for odor in water	ASTM D 1292
Method of measurement of odor in atmospheres (Dilution method)	ASTM D 1391
Practice for referencing suprathreshold odor intensity	ASTM E 544

PRACTICAL METHOD FOR SHELF-LIFE ESTIMATION

THE MAIN CAUSES OF QUALITY CHANGING

1. Direct effects :

   - Chemical reactions

     Oxidation : rancidity
     colour changing
     vitamin degradation

     New (strange) molecule formation

   - Physical origin

     Temperature : physical state changing
     water content changing
     rheological properties changing

     Relative humidity : water activity changing
     water absorption or desorption

     Radiation (light) : colour changing and catalytic effect

   - Biological origin :

     Hygienic state changing
     Enzymes activity changing

2. Indirect effects :

   - Chemical origin :
     Catalytic effect of heavy metals and radiation

   - Physical origin :
     Migration
     Penetration

   - Biological origin :
     Propagation of microorganisms
     Toxin production

THE MAIN SOURCES OF QUALITY CHANGING

1. Oxidation

   - High or relatively high fat content (unsaturated fatty acids)
   - High or relatively high protein content
   - Coloured with hemoglobine
   - Fried with lard or vegetable oil
   - High or relatively high free radical content
   - High or relatively high volatile oil content
   - Vitamin C content
   - Vitaminisation

2. Water absorption or desorption

   - Dried products
   - Instant products
   - Freeze dried foods
   - Gelatinized products
   - Foods in gel-form
   - Foods in foam-form
   - Plastified products
   - Food with high or relatively high water content

3. Off-flavour production

   - High or relatively high protein content
   - Products with relatively high enzyme content
   - Strange material formation
   - Strange materials up-take by migration or penetration

4. Microorganisms activity

   - Mould formation
   - Yeast propagation
   - Bacteria infection
   - Toxin production

BASIC INFORMATION ABOUT THE FRESH OR PROCESSED FOOD

1. Food name :

   - Trade name :
   - Manufacturer :

2. Main components (raw materials) :

Serial number	Component name	Quantity (W/W)	Quality* (Standard sign)	Origin (Manufacturer, dealer, etc.)

* If the quality of component is not standardized, then data on the main quality parameters.

3. Quality control data of main components (arrival in factory) :

   - Component name:
   - Serial number:
   - Tested properties:
   - Test method(s) and equipment:
   - Results of measurements:
   - Final score:
   - Title and sign of standard used:

4. Storage (main components) before processing

- Component name:
- Serial number:
- Storage time (day):
- Storage parameters:

  Temperature (range):
  Relative humidity (range):
  Light:
  Packaging:
- Place of storage

5. Quality control data of main components (after storage, before usage):

- Component name:
- Serial number.
- Tested properties:
- Test method(s) and equipment:
- Results of measurements:
- Final score:
- Title and sign of standard used:

6. Data of processing (till packaging):

- Main procedures of technology (for each):

  Name of unit operation:
  Equipment of unit operation (main parameters):
  Main parameters of treatment:
    Time (min.):
    Temperature (°C):
    Pressure (kPa):
    Others:

- Storages between treatments (for each):

  Container(s) type and data:
  Main parameters of product:

Temperature (°C):

Relative humidity (%):

Light:

Time:

Place:

7. Quality control during processes

- Sampling places (for each):
  Sampling time:
  Tested property(ies):
  Test method and equipment:
  Results of measurements:
  Title and sign of standard used:
- Feed-back procedure:
  Time after sampling:
  Place(s) of feed-back:
  Consequencies of feed-back:
- Final result (score):

8. Storage before packaging (according to technology)

- Container(s) type and data:
- Main parameters of product:
- Time:
- Place:
- Temperature:
- Relative humidity:
- Light:
- Expected changing of product:
- Results of quality control:
- Final score:

BASIC INFORMATION ABOUT THE PACKAGING

1. Main parameters of package:

   - Packed product:
   - Packed unit:
   - Package form/design:
   - Printing/labeling:
   - Relevant standard(s):

2. Packaging material(s), containers, auxiliaries and others:

Serial number	Name		Mass (g)	Surface (cm^2)	Transparency (%) and colour	Quality* (Standard sign and title)	Origin (Factory, dealer)
	Chemical	Trade					

* If the quality is not standardized, then data on the main quality paraters.

3. Quality test of packaging material(s)/containers and auxiliaries:

   - Tested property (ies):
   - Test method(s) and equipment:
   - Parameters of conditioning:
   - Results of measurements (main values and standard deviations):
   - Final score:
   - Title and sign of standard used:

4. Packaging procedure

- Main steps and parameters of package formation (or preformed container used):

    Modified atmosphere (it it is used):
    Machinery:
    Sealing:
    Auxiliaries usage:
    Hygienic state:

- Filling:

    Method:
    Machinery:

- Sealing:

    Method:
    Closure and/or auxiliaries used:
    Machinery:

- Labeling

    Method:
    Material(s):
    Machinery:

- Atmosphere in packaging room:

    Atmosphere (it is modified):
    Temperature:
    Relative humidity:
    Light:
    Hygienic state:

5. Quality control after packaging:

- Sampling

    Number of shifts
    Number of samples per shift

Sampling time per shifts:

Sampling places per shifts:

Duration from sampling to test (h):

Mode of sample transportation to test:

- Tests (number of parallels and repeats per shifts)

  Properties:

  Method (if they are standardized the sign and title of standard used):

  Evaluation of measurements:

  Final result (score):

- Feed-back procedure:

  Time after sampling:

  Place(s) of feed-back:

  Consequencies:

- Quality certification:

6. <u>Storage in factory:</u>

- Storage units and forms:
- Method(s) of unit formation:
- Machinery:
- Storage time :
- Main parameters of place :

  Temperature (max. and min., avarage):

  Relative humidity (max. and min., average):

  Light :

  Hygienic state:

- Handling tool(s) and equipment:

SHELF-LIFE DECLARATION

1. Investigated properties of packed product:

   - Test methods (if they are standardized the sign and title of standard used):

2. Evaluation of measurements (For details see Recommendation of mathematical statistical analysis of experimental data for shelf-life estimation)

   - Curve fitting

   According to the parameters of treatments (e.g. storage temperature is 30°C and 22°C and 14°C) in the function of storage time we search the curves which approach most the significant parameters change in the function of storage time. The curves would be:

   linear : $y = a - bx$

   quadrat : $y = a - bx^2$

   exponential : $y = ae^{-bx}$

   sigmoid : $y = a - \frac{a}{1 + e^{bx}}$

   hyperbola : $y = ax^{-b}$

   where

   y = value of "critical" property changed

   a = original (start) value of quality

   b = quality changing rate constant

   x = storage time

   For the calculation in practice we have to transform the equations in linear form.

- Comparisons of curves

To know the critical property(ies) of product investigated we have to compare the steepness of curves according to the value of k-th and l-th curve

$$t = \frac{b_k - b_l}{S_d}$$

where

b_k = regression coefficient of k-th curve

b_l = regression coefficient of l-th curve

S_d = standard error of differences between the steepness of two (k-th and l-th) curves

- Critical property(ies) determination

After we compared the steepness of curves, we received the most rapidly changing parameter (property) of stored food or packaging material or package tested in the function of storage time. The most rapidly changing parameter gives the so-called "critical" property of material investigated.

- Shelf-life estimation

According to the national or international standards we have to know the threshold value of most rapidly changing attribute ("critical" property) of our food or our goods. On the base of threshold value of critical property we can calculate the shelf-life of material investigated by interpolation of quality changing curve and equation, respectively. The result of interpolation gives the "critical" time of storage which means the shelf-life of investigated good. If the threshold value is not standardized you can use 33.33% decreased value according to the international practice or other decreased value according to the national rules.

- Control calculations and determination of confidency belt

We will receive the interval confidency of curve - the curve gives the base of shelf-life calculation - if we calculate the standard error of expected value. For shelf-life calculation it is the best approach to achieve the smallest standard error of expected value. The calculated standard error gives the accuracy of shelf-life determined.

Standard error calculations of expected value (y) determines the uncertainty of shelf-life estimated as it is following:

$$S_y^2 = \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{n-2}$$

where

y_i = measured value of "critical" property at time i-th

$\hat{y}_i$ = estimated (calculated) value of "critical" property at time i-th

n = number of measurements

3. <u>Shelf-life declaration</u> according to food, processing, packaging, storage circumstances (temperature, relative humidity and light).

OBJECTION ANALYSIS OF PACKED FRESH AND PROCESSED FOODS

1. Objection of packed products:

- Number of objection (per year, per half-year, per month):
- Source of objection:

Form	Sources						Others
	Packed food			Marketing			
	Quantity	Quality	Shelf-life	Transportation	Storage	Sale	
Consumer							
Retailer							
Other							

- Number of objected products:

Form	Sources						Others
	Packed food			Marketing			
	Quantity	Quality	Shelf-life	Transportation	Storage	Sale	
Consumer							
Retailer							
Other							

2. Objection analysis according to food quality (see Chapter 3 for qualification of fresh and processed food to packaging):

3. Objection analysis according to shelf-life of food, including packaging (see Chapter 4 for qualification of fresh and processed food packaging):

4. Objection analysis according to transportation:

- Packaging (dealer and transportation):
    - Unit(s):
    - Design/form:
- Transportation mode (for each mode):
    - Distance (km):
    - Time (h):
    - Temperature (range and avarage):
        - Inside (the wagon) (°C):
        - Outside (°C):
    - Relative humidity (range and average):
        - Inside (the wagon) (%):
        - Outside (%):
    - Shocking effects (max. in g):
        - Amplitudo:
        - Frequency (Hz):
    - Collision effects (max. in g):
- Handling:
    - Number of transfering:
    - Tool/equipment of handling:
    - Dropping (sum and maximum in g):
- Used quality control of transporting packages:
    - Tested properties:
    - Test methods and equipment:
    - Title and sign of standard used:
    - Results achieved:
    - Quality certification issued by:
- Summary of objection analysis:

5. Objection analysis according to marketing:

- Storage:
    - Unit(s) of packages:
    - Time (hour and day):

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g is the unit of gravitational acceleration, in cases above

Temperature (average, max. and min.) (°C) :

Relative humidity (average, max. and min.) (%):

Light:

Other materials and product in same room:

Remarks of retailer(s):

- Sale:

  Unit(s) of packages:

  Temperature (average, max. and min.) (°C):

  Relative humidity (average, max. and min.) (°C):

  Light:

  Remarks of retailer(s):

- Recommendations of retailers:

  Shelf-life:

  Packaging:

  Design/form:

  Unit:

  Quality (including sealing):

  Labeling:

  Method of distribution:

  Product handling:

  Others:

6. Conclusions for improvement

- Quality control system's changing including feed-back method
- Improvement of processing
- Improvement of packaging technique

  Material

  Container

  Auxiliaries

  Machinery (package formation, filling, sealing, labeling, others)
- Quality control method's changing of packaging
- Improvement of storage and transportation
- New way for marketing

MATHEMATICAL STATISTICAL ANALYSIS OF EXPERIMENTAL DATA FOR SHELF-LIFE ESTIMATION

Data analysis of measurements

Calculation of mean values and standard deviations of parallel measurements.

$$\bar{x} = \frac{1}{n}(x_1 + x_2 + x_3 + \dots + x_{n-1} + x_n) = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$s^2 = \frac{1}{n-1}(x_1 - \bar{x})^2 + \dots + (x_n - \bar{x})^2 = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

$$\sqrt{s^2} = \mp s$$

where

$\bar{x}$ = average value

s^2 = variance

$\mp s$ = standard deviation

Calculation (control) of homogeneity of variances according to treatments (e.g. packaging, temperature, storage time) or to attributes investigated (e.g. changing of vitamin C content, cell count number, sensory properties). It is the Bartlett type χ^2-test, as it follows:

$$\chi^2 = \frac{2.3026}{A}\left[f \log s^2 - \sum_{j=1}^{r}(n_j - 1)\log s_j^2\right]$$

where

$$A = 1 + \frac{1}{3(r-1)}\left(\sum_{j=1}^{r}\frac{1}{n_j - 1} - \frac{1}{f}\right)$$

$$f = \sum_{j=1}^{r} n_j - r$$

$$s^2 = \frac{1}{f}\sum_{j=1}^{r}(n_j - 1)\, s_j^2$$

and

where

j = number of groups (1,2,3, . . . j-1, j)

s_j^2 = variance of group j-th

n = number of measurements inside the groups

r = total number of groups (1+2+3+. . .+j-1+j)

(n_j-1) = degree of freedom of group j-th

f = total number of measurements reduced, with total number of groups

$r-1$ = degree of freedom of χ^2-test

If the variances are homogeneous we may calculate the effect of certain treatment (e.g. packaging, temperature, storage time) by one-way analysis of variances or the combined effects (e.g. packaging and temperature, packaging and storage time, temperature and packaging) by two-ways analysis of variances. It is the F-test, which would be applied to special cases by Student type t-test or by Streuli type t-test.

One-way analysis of variance

Total sum of square : $SQ_T = \sum_{i=1}^{k} \sum_{j=1}^{n_i} (x_{ij}-\bar{\bar{x}})^2$; FG = N-1

Variances among the samples (groups) : $SQ_A = \sum_{i=1}^{k} n(\bar{x}_i-\bar{\bar{x}})^2$; FG = k-1

Variances inside the samples (groups) : $SQ_I = \sum_{i=1}^{k} \sum_{j=1}^{n} (\bar{x}_{ij}-\bar{\bar{x}})^2$: FG = N-k

where

(x_{ij}) = values of samples in groups $(x_1 . . . x_k)$

(i) = serial number of groups (i. . .k)

(n_{ij}) = number of samples in groups $(n_i . . . n_k)$

$\bar{x}$ = average value of groups $(\bar{x}_i \ldots \bar{x}_k) = \frac{1}{n_j} \sum_{j=1}^{n_i} x_{ij}$

$\bar{\bar{x}}$ = mean average value of groups $(\bar{\bar{x}}_i \ldots \bar{\bar{x}}_k) = \frac{\sum_{i=1}^{k} \sum_{j=1}^{n_i} x_{ij}}{N}$

N = number (total) of samples

k = number of groups

(s_i^2) = variances $(s_i^2 \ldots s_k^2)$

Result of variance analysis

Source of variance	Sum of square	Degrees of freedom	Mean Square	F-value
Total	SQ_T	N-1		
Among the groups	SQ_A	k-1	$\frac{SQ_A}{k-1} = S_A^2$	$\frac{S_A^2}{S_I^2}$
Inside the groups	SQ_I	N-k	$\frac{SQ_I}{n-k} = S_I^2$	

Two-ways analysis of variance to determine the significance of two different treatments (aspects)

Total sum of square : $SQ_T = \sum_{i=1}^{k} \sum_{j=1}^{m} (x_{ij} - \bar{\bar{x}})^2$; FG = k m-1

Deviation of variances among the groups A : $SQ_A = \sum_{i=1}^{k} m\,(\bar{x}_i - \bar{\bar{x}})^2$; FG = k-1
(A aspect)

Deviation of variances among the groups B : $SQ_B = \sum_{j=1}^{m} k\,(\bar{x}_j - \bar{\bar{x}})^2$; FG = m-1
(B aspect)

Deviation of variances accident inside the groups

$$SQ_I = \sum_{i=1}^{k} \sum_{j=1}^{m} (x_{ij} - \bar{x}_i - \bar{x}_j + \bar{\bar{x}})^2 \; ; \; FG = (k-1)(m-1)$$

where

$(x_{ij}-km)$ = values of samples in groups according to A_{ik} aspect

$(x_{im}-kj)$ = values of samples in groups according to B_{jm} aspect

$A_1, A_2 \ldots A_i \ldots A_k$ = serial number of groups according to A aspect

$B_1, B_2 \ldots B_j \ldots B_m$ = serial number of groups according to B aspect

Result of variance analysis

Source of variance	Sum of square	Degrees of freedom	Mean square	F-value
Total	SQ_T	k m-1		
A_i effects	SQ_A	k-1	$\frac{SQ_A}{k-1} = S_A^2$	$F_A = \frac{S_A^2}{S_I^2}$
B_j effects	SQ_B	m-1	$\frac{SQ_B}{m-1} = S_B^2$	$F_B = \frac{S_B^2}{S_I^2}$
Error accident	SQ_I	(k -1)(m-1)	$\frac{SQ_I}{(k-1)(m-1)} = S_I^2$	

Note : The equations are valid when the regression is linear. In other cases we have to transform the correlations or if it is not possible, to approach e.g. by parabol ($y = a+bx+cx^2$) or other equation. (See the list of references.)

If the variances are not homogeneous according to the Bartlett type χ^2-test we have to make control calculation to determine the out-standing values by Dixon type r-criteria.

Data would be ordered according to their value and calculate as it follows:

- Number of data : 3-7 than $r_{10} = \frac{x_1-x_2}{x_1-x_n}$

  8-10 than $r_{11} = \frac{x_1-x_2}{x_1-x_{n-1}}$

  11-13 than $r_{21} = \frac{x_1-x_3}{x_1-x_{n-1}}$

  14-25 than $r_{22} = \frac{x_1-x_3}{x_1-x_{n-2}}$

- The order of data is $x_1, x_2 \dots x_{n-1}, x_n$

We may eleminate the out-standing data according to the relevant table. (See the references.)

Student type t-test

$$t = \frac{\bar{x} - \bar{y}}{\sqrt{\frac{Q_x+Q_y}{n+m-2} \cdot \frac{n+m}{n\,m}}}$$

where

$\bar{x}$ = mean value of x samples

$\bar{y}$ = mean value of y samples

$$Q_x = \sum x^2 - \frac{(\sum x^2)}{n}$$ (sum of square of x samples)

$$Q_y = \sum y^2 - \frac{(\sum y)^2}{m}$$ (sum of square of y samples)

n = number of x samples

m = number of y samples

Control calculation for deviation of variances with F-test

$$F = \frac{s_x^2}{s_y^2}$$

where

$$s_x^2 = \frac{Q_x}{n-1} \quad \text{and} \quad s_y^2 = \frac{Q_y}{n-1}$$

If the result of F-test does not show significant differences between the variances of x samples and y samples, we may use the Student type t-test. If the result of F-test shows inhomogeneity between the variances, we have to use the provisoric statistic. (For more details see the references.)

Streuli type t-test

The test is applicable when the data are paired.

$$t_d = \frac{\bar{d}\sqrt{n}}{s}$$

where

$$\bar{d} = \frac{\sum d}{n},$$

$$s = \sqrt{\frac{\sum d^2 - \frac{(\sum d)^2}{n}}{n-1}}$$

and

d = difference of data paired

n = number of data paired

Shelf-life estimation

For shelf-life estimation we have to search the correlation between the storage time - as independent variable - and the changing characteristic property(ies) of product investigated, using the least squares method for curve fitting.

Curve fitting

According to the parameters of treatments (e.g. storage temperature is 30°C and 22°C and 14°C) we form homogeneous populations and in the function of storage time we search the curves which approach most the significant parameters change in the function of storage time. The curves would be:

linear : $y = a - bx$

quadrat : $y = a - bx^2$

exponential : $y = ae^{-bx}$

sigmoid : $y = a - \frac{a}{1 + e^{bx}}$

hyperbola : $y = ax^{-b}$

where

y = value of "critical" property changed

a = original (start) value of quality

b = quality changing rate constant

x = storage time

For the calculation in practice we have to transform the equations in linear form. The linear regression analysis gives information about the tightness of curve fitting.

Linear regression analysis

The equation is : $y = a+bx$, and for shelf-life estimation it is

$y = a-bx$, respectively

Calculation of regression coefficient (b)

$$b = \frac{\sum x_i y_i - \frac{(\sum x_i)(\sum y_i)}{n}}{\sum x_i^2 - \frac{(\sum x_i)^2}{n}} = \frac{SP}{SQ_x}$$

Calculation of regression constant (a)

$$a = \bar{y} - b\bar{x}$$

Calculation of correlation coefficient (r) and determination coefficient (r^2) to qualify the curve fitting

$$r = \frac{\sum x_i y_i - \frac{(\sum x_i)(\sum y_i)}{n}}{\sqrt{\left[\sum x_i^2 - \frac{(\sum x_i)^2}{n}\right]\left[\sum y_i^2 - \frac{(\sum y_i)^2}{n}\right]}} = \frac{SP}{SQ_x SQy} =$$

$$= \frac{\sum xy}{\sum x^2 \sum y^2}$$

and

$$r^2 = \frac{SP^2}{SQ_x SQ_y}$$

where

y = expected value (dependent variable)

a = regression constant

b = regression coefficient

x = independent variable (usually it is the time)

n = number of measurements

FG = degree of freedom (n-1)

SQ_x = sum of square of x (independent variable)

SQ_y = sum of square of y (dependent variable)

SP = sum of probability of x_i and y_i variables

r = correlation coefficient

r^2 = determination coefficient

and

$$SQ_x = \sum_1^i x^2 - \frac{\left(\sum_1^i x\right)^2}{n}$$

$$SQ_y = \sum_1^i y^2 - \frac{\left(\sum_1^i y\right)^2}{n}$$

$$SP = \sum_1^i xy - \frac{\left(\sum_1^i x\right)\left(\sum_1^i y\right)}{n}$$

The value of correlation coefficient (r) gives information about the quality of curve fitting (the absolute value is r=1.00).

Selection of critical property(ies)

We may suppose the t-distribution of regression coefficients and degree of freedom in (2n-4) where n is the number of measurements and than we can compare the steepness of curves. The result of calculation gives the most rapidly changing parameter (property) of stored food or packaging material or package tested in the function of storage time. The most rapidly changing parameter gives the so-called "critical" property of material investigated.

To know the critical property(ies) of product investigated we have to compare the steepness of curves according to the value of k-th and l-th curve

$$t = \frac{b_k - b_l}{S_d}$$

where

b_k = regression coefficient of k-th curve

b_l = regression coefficient of l-th curve

S_d = standard error of differences between the steepness of two (k-th and l-th) curves

and

$$S_d = \sqrt{S^2_{b_k} + S^2_{b_l}}$$

where

$S^2_{b_k}$ = standard error of regression coefficient of k-th curve

$S^2_{b_l}$ = standard error of regression coefficient of l-th curve

and

$$S^2_{b_k} = \frac{\sum y^2 - \frac{(\sum y)^2}{n} - \frac{\left(\sum xy - \frac{\sum x \sum y}{n}\right)^2}{\sum x - \frac{(\sum x)^2}{n}}}{\left[\sum x - \frac{(\sum x)^2}{n}\right](n-2)}$$

$$S^2_{b_l} = \frac{\sum y^2 - \frac{(\sum y)^2}{n} - \frac{\left(\sum xy - \frac{\sum x \sum y}{n}\right)^2}{\sum x - \frac{(\sum x)^2}{n}}}{\left[\sum x - \frac{(\sum x)^2}{n}\right](n-2)}$$

Curve fitting accuracy

We will receive the interval confidency of curve - the curve gives the base of shelf-life calculation - if we will calculate the standard error of expected value. For shelf-life calculation it is the best approach to achieve the smallest standard error of expected value. The calculated standard error gives the accuracy of shelf-life determined.

Standard error calculations of expected value (y) determines the uncertainty of shelf-life estimated as it is following:

$$S_y^2 = \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{n-2}$$

where

y_i = measured value of "critical" property at time i-th

$\hat{y}_i$ = estimated (calculated) value of "critical" property at time i-th

n = number of measurements

Calculation of regression constant (a) variance to determine the uncertainty of original (start) value of quality

$$S_a^2 = \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2 \sum_{i=1}^{n} x_i^2}{n(n-2) \sum_{i=1}^{n} (x_i - \bar{x})^2}$$

where

$\bar{x}$ = mean value of independent variable

x_i = value of independent variable at time i-th

Calculation of regression coefficient's (b) variance to determine the uncertainty of rate constant of quality changing

$$S_b^2 = \frac{\sum_{i=1}^{n} (y_i - \hat{y}_i)^2}{(n-2)\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

According to the national or international standards we have to know the threshold value of most rapidly changing attribute of our food or packaging material. On the basis of threshold value of critical property we can calculate the shelf-life of material investigated by interpolation of quality changing curve and equation, respectively. The result of interpolation gives the "critical" time of storage which means the shelf-life of investigated good.

References

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SHELF LIFE-ESTIMATION

An explanation of basic theory of food deterioration and shelf-life estimation for fresh and processed food

INTRODUCTION

The topics of lecture was constructed according to the request of counterpart. It contains a selection of relevant chapters of packaging science and technology and of food science and technology, respectively. The main target of lecture was to implement the theory and praxis of shelf-life estimation of fresh and processed food. Two booklets were also prepared to complete the lecture; one is Practical Method for Shelf-life Estimation, and the other is Mathematical Statistical Analysis of Experimental Data for Shelf-life Estimation.

The lecture was given from 4th of July, 1991 till 28th of August, on every Wednesday between 9-11 in Thai Packaging Centre's Seminar Room. The selected topics of lecture cover a post-graduate course on University level.

Shelf-life estimation

(Lecture scheme)

Definition of food

- Healthy food
- Food safety

Characterization of food

- Chemical properties
- Physical properties
- Rheological behaviour
- Microbiological aspects
- Nutritive value
- Sensoric properties

Methods to characterize the food

- Instrumental methods
- Sensoric methods
- In-vivo and in-vitro methods
- Clinical tests

Food composition

- Organic components
    = Proteins
    = Carbohydrates
    = Fats
    = Others
- Inorganic components
    = Salts (macro elements)
    = Trace (micro) elements
- Water

Relatively stable and changing attributes of food

- Stable attributes
  - = Physical state (liquid, puree, solid)
  - = Quantity (mass, volume)
  - = Density (mechanical, optical)
  - = Composition

- Changing attributes
  - = Ratio of organic components concentration
  - = Structure of molecules
  - = Rheological behaviour
  - = Biological value
  - = Hygienic state

Quantification of attributes regarding to standards

- Quality grades
- Problem of additives (positive and negative lists)
- Strange material in food
- Food enrichment
- Energy content

Factors influence the food quality

- Raw materials
- Processing and treatment (technology)
- Enzymes and enzyme systems
- Microorganisms (bacteria, yeasts, moulds)
- Radiation (light, ionizing ray)
- Storage (temperature, relative humidity)
- Transportation and material handling

Effect of packaging on food quality changing

- Radiation barrier property of packaging materials
  = Intensity of radiation
  = Energy of radiation
  = Light (radiation) permeability of some food packaging material

- Correlation between the radiation energy and the activation energy of chemical reactions
  = Important ranges of radiation
  = The effect of radiation on different food products

- Radiation (light) as an energy source for quality changing
  = Radical formation
  = Aldehyde, alcohol and ketone formation

- Barrier behaviour and structure of packaging materials
  = Mass transfer through polymers
  = Crystall (ordered part) contents and distribution in solid polymer films
  = Importance of amorphous (unordered part) contents to value of diffusion and solubility coefficients
  = Crystall (ordered part) content and free path (way) length in solid polymers
  = Solubility and amorphous (unordered part) contents in polymer films

- Chemical (molecular) structure and physical, chemical, mechanical properties of polymers
  = Low and high density polyethylene
  = Isotactic, syndiotactic and atactic polypropylene
  = Poly(vinyl chloride) and poly(vinylidene chloride)
  = Polystyrene and poly(methyl metacrylate)
  = Polyesters and polycarbonates

- Problems of heat sealing

- Advantage and disadvantage of crystallic polymers
  = Permeability
  = Heat resistance
  = Heat sealing property
  = Mechanical properties
  = Chemical resistance

- Packaging material combinations
  - = Methods of combinations
    - Lamination
    - Coextrusion
    - Coating
  - = Main types of combinations
    - Paper + polymer
    - Paper + alu-foil
    - Paper + alu-foil + polymer
    - Polymer + polymer
    - Polymer + alu-foil
    - Regenerated cellulose + polymer
  - = Metal vapourized packaging materials
  - = Permeability of combined materials
    - Water vapour
    - Gas
    - Light
  - = Properties of combined materials
    - Chemical properties
    - Physical properties
    - Mechanical properties
  - = Heat sealing of combined materials
- Modified atmosphere packaging
  - = Benefit of modified atmosphere
  - = Vacuum packaging
  - = Vacuum and inert gas packaging
  - = Gas combinations and food protection
  - = Packaging materials for modified atmosphere packaging
  - = Main fields of modified atmosphere packaging
    - Fresh fruits and vegetables
    - Meat products
    - Dairy products
    - Ground coffee
- Effect of printing on packaging quality

Mechanism and kinetic of quality changing

- Chemical origin
  - = Order of reactions
  - = Reaction rate and the temperature
  - = Enzymic reactions
  - = Water activity
  - = Concentration of free radicals
  - = Inter-molecular binding

- Physical origin
  - = Physical state and molecular activity
  - = Water (wet) content and bound water
    - Physically (mechanically) bound water - saturation
    - Capillary water
    - Polylayer water
    - Bi- and monolayer water - drying
  - = Gel state
  - = Role of active surface
    - Physical state and radiation effect
    - Porousity and oxidation
  - = Rheological properties and texture
    - Chewing property
    - Elasticity and physical state
    - Foams

- Biological origin
  - = Origin of infection
    - Raw materials and additives (e.g. spices)
    - Water
    - Air
    - Surfaces of tools, containers, tanks and equipment
    - Human origin
  - = Main types of microorganisms
    - Bacteria (e.g. enterobacteriaceae, salmonella, clostridia, coccus)
    - Yeasts (e.g. saccharomyces, candida, rhodotorula)
    - Moulds (e.g. mucor, rhisopus, botrytis, fusaria, aspergillus, penicillium)

= Effects of infection

Serious diseases (e.g. salmonella typhi, clostridium botulinum, yeast origin mycotoxin)

Moderate diseases (e.g. bacillus cereus, clostridium perfingens other salmonella varieties)

Conditional diseases (e.g. some of streptococcus, escherichia, aerob spore forming tribes)

<u>Shelf-life estimation of fresh and processed foods</u>

- Selection of most rapidly changing component(s) or property(ies)
  - = Chemical origin, and/or
  - = Physical origin, and/or
  - = Biological origin
- Characterisation of quality changing
  - = Curve fitting
  - = Comparison of curves
    - Regression coefficient calculation (b)
    - Regression constant calculation (a)
    - Curve steepness comparison (b_k, b_l)
    - Determination of critical property
- Control calculations
  - = Standard error of regression coefficient (b)
  - = Standard error of regression constant (a)
  - = Standard error of expected value (y)
- Shelf-life declaration and its accuracy
- Problems of accelerated storages

Possibilities of shelf-life extension

- Food quality improvement

    = Raw material
    = Development of food processing
    = Improvement of hygienic circumstances
    = Storage technology improvement of raw materials and half product

- Packaging quality improvement

    = Packaging technology improvement
    = Improvement of barrier properties
        Water vapour
        Gas
        Light
    = Improvement of sealing or closure
    = Active surface reduction, new design
    = Wall thickness changing
    = Modified atmosphere

- Storage and transportation improvement

    = Temperature decreasing
    = Relative humidity changing
    = Radiation (light) reduction
    = Cushioning improvement
    = Storage and transportation time reduction
    = Moderation of material handling

- Marketing

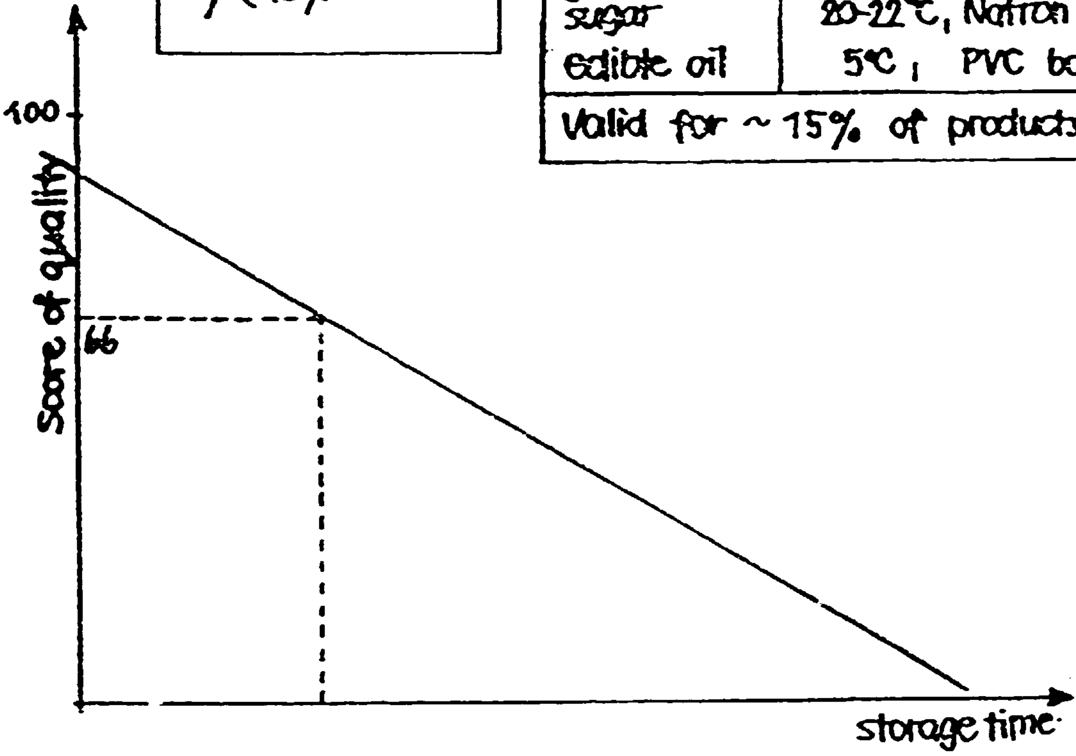
    = Improvement of sale
    = Storage improvement
    = Turnover increasing

MODEL

$y = a - bx$
$a_{max} \gg a \gg 2/3\, a_{max}$
$S_y < 10\%$

APPLICATION

Products	Storage and Packaging
Poultries	-18°C, -15°C; Polyethylene bag
salamies	5-7°C, —
powdered sugar	20-22°C, Polyethylene bag
granulated sugar	20-22°C, Natron paper
edible oil	5°C, PVC bottle
Valid for ~ 15% of products	



LINEAR CHANGE OF QUALITY CHARACTER

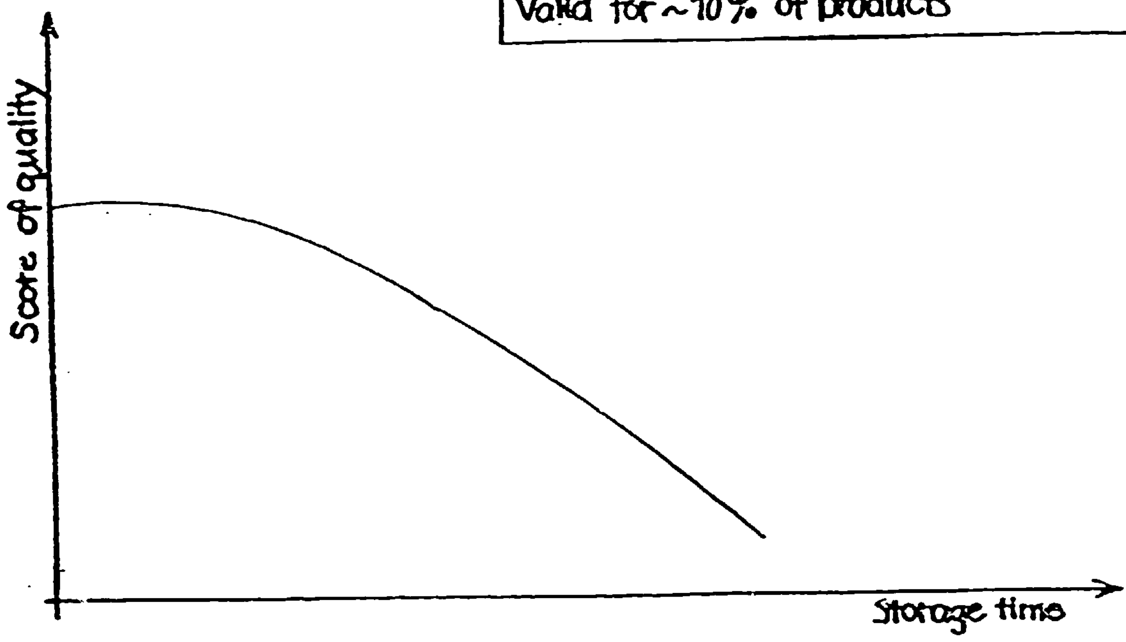
Linear type mathematical model to approach the quality changing of approximately 15% of food products stored in different temperatures and containers

MODEL

$y = a - bx^2$
$a_{max} \geq a \geq 2/3\, a_{max}$
$S_y < 10\%$

APPLICATION

Products	Storage and packaging
quick frozen foods	-18°C – +5°C; plastic bags, paper boxes, etc.
Valid for ~10% of products	



QUADRATIC CHANGE OF QUALITY CHARACTER

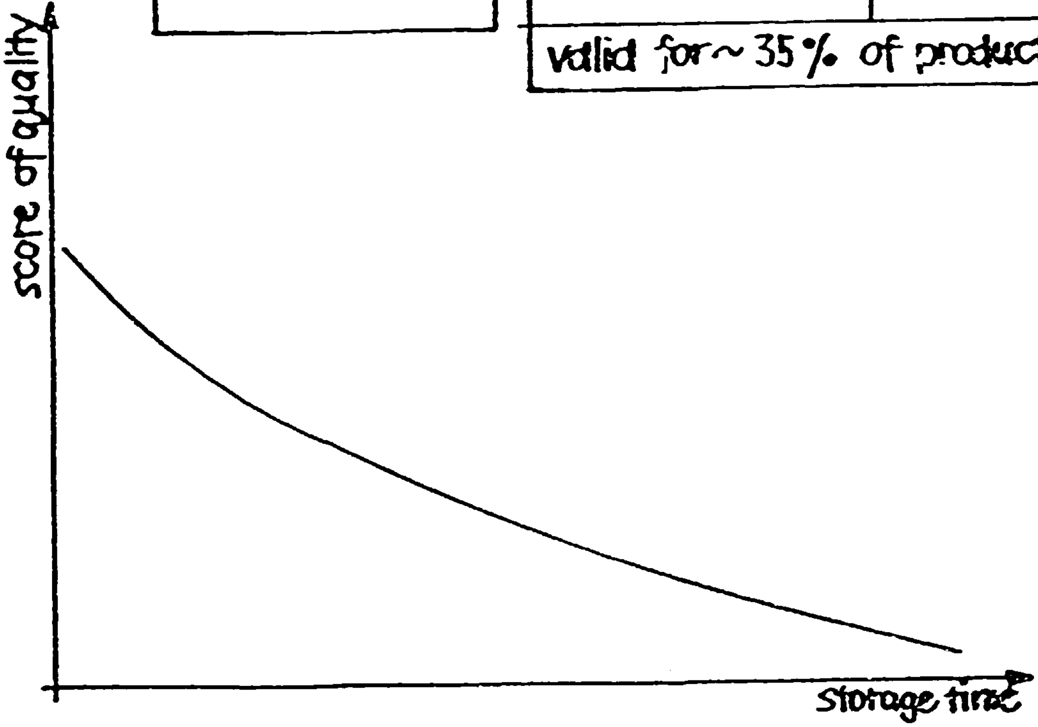
Quadratic type mathematical model of approach the quality changing of approximately 10% of food products stored in different temperatures and containers

MODEL

$y = ae^{-bx}$
$a_{max} \geq a \geq 2/3\, a_{max}$
$S_y < 10\%$

APPLICATION

Products	Storage and packaging
leg of pork	5-7°C foil-wrapped
canned meals	20-22°C tin-can
egg nog	20-25°C bottle
baker's yeast	5°C paper
valid for ~ 35 % of products	



EXPONENTIAL CHANGE OF QUALITY CHARACTER

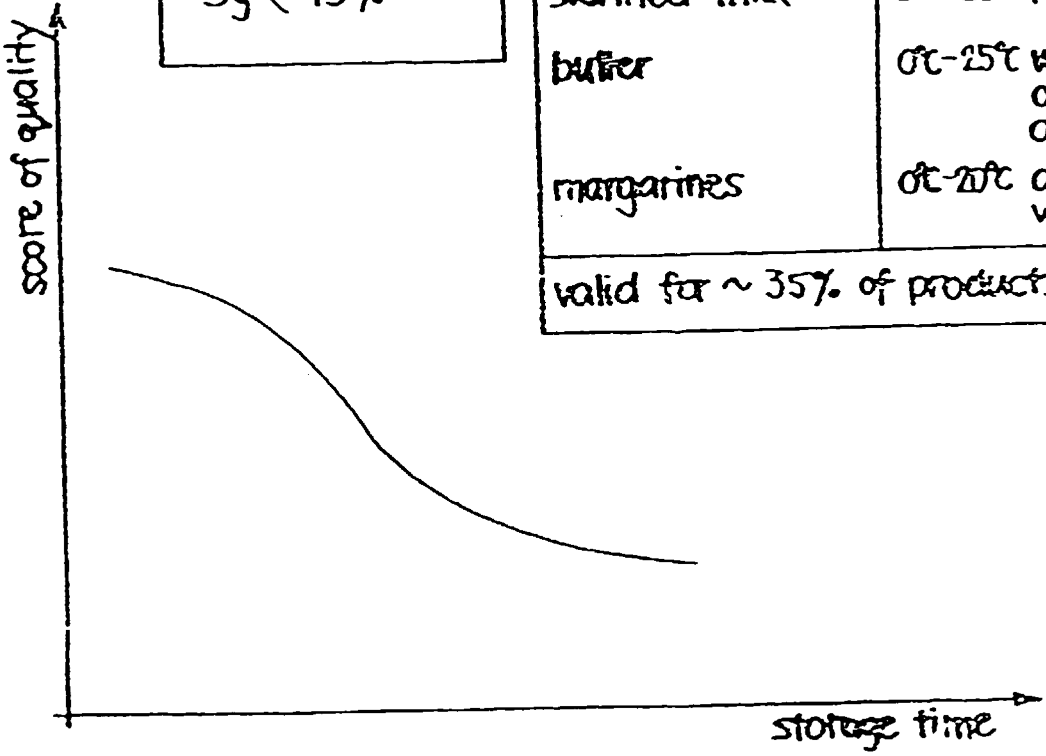
Exponential type mathematical model to approach the quality changing of approximately 35% of food products stored in different temperatures and containers

MODEL

$y = a - \frac{a}{1 + e^{bx}}$
$a_{max} \geq a \geq \frac{2}{3} a_{max}$
$S_y < 10\%$

APPLICATION

Products	Storage and packaging
bakery goods	20-25°C paper wrapped
soft drinks	5°C, 20-22°C bottles
flours	20-22°C paper & textile bags
pasteurized skinned milk	0°C-25°C polyethylene bag
butter	0°C-25°C wrapped or plastic container
margarines	0°C-20°C alufoil wrapped
valid for ~ 35% of products	



SIGMOID CHANGE OF QUALITY CHARACTER

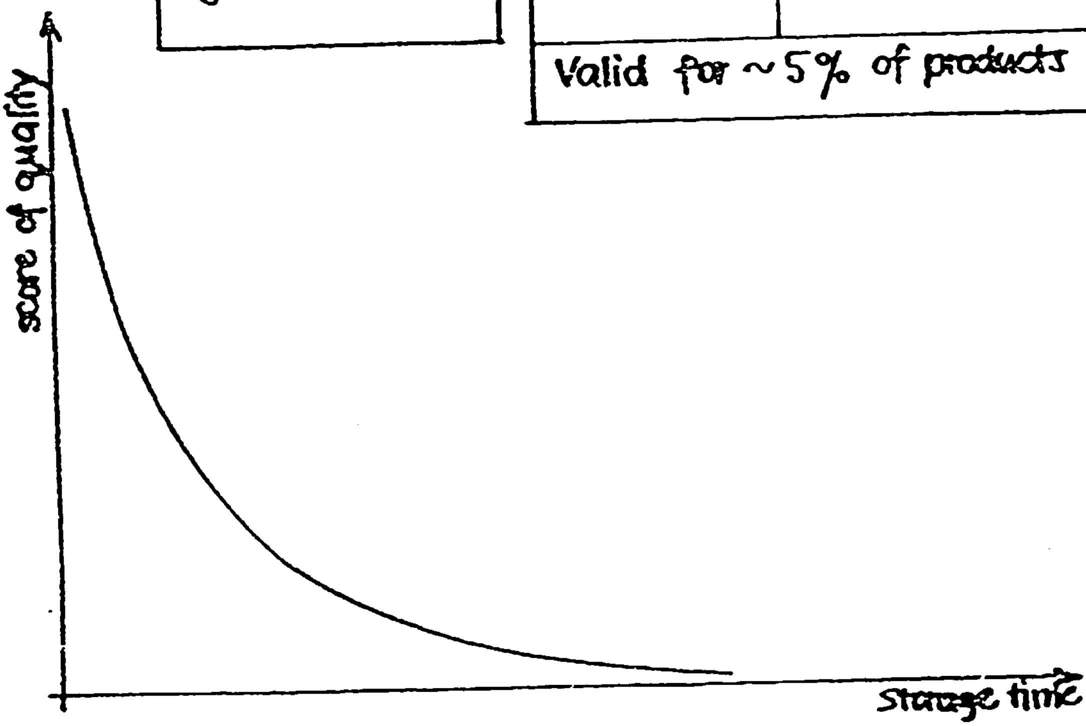
Sigmoid type mathematical model to approach the quality changing of approximately 35% of food products stored in different temperatures and containers

MODEL

$y = ax^{-b}$
$a_{max} \geq a \geq 2/3\, a_{max}$
$S_y < 10\%$

APPLICATION

Products	Storage and packaging
sausages	20-22°C —
sliced bacon	20-22°C cellothene bag
leg of pork	20-22°C foil-wrapped
fresh fruits	15°C over-wrapped trays
Valid for ~5% of products	

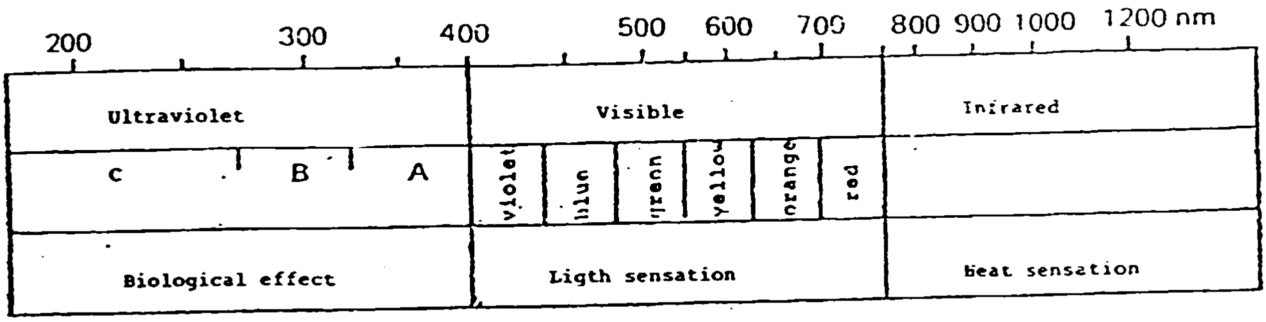


HYPERBOLICAL CHANGE OF QUALITY CHARACTER

Hyperbolic type mathematical model to approach the quality changing of approximately 5% of food products stored in different temperatures and containers

RADIATION ENERGY AND ACTIVATION ENERGY

The absorbed radiation energy provides the activation energy necessary for chemical reactions



Important ranges of radiation

The values of activation energy (for example) are:

infra-red radiation	($\lambda > 8000 \times 10^{-8}$ cm)	: $E \leq 35 \times 4.5$ J/mol
yellow radiation	($\lambda = 5700 \times 10^{-8}$ cm)	: $E = 50 \times 4.5$ J/mol
ultra-violet radiation	($\lambda < 4000 \times 10^{-8}$ cm)	: $E \geq 71 \times 4.5$ J/mol

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SHELF-LIFE AND PACKAGING OF FOOD

(Review)

Prepared by

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October 1991

INTRODUCTION

For the request of counterpart a review was worked out to introduce a significant part of international scientific and technical literature about the mechanism and kinetic of food quality changing with especial regarding to packaging.

The review includes the mass transfer theory and practice, the correlations between polymer structure and physical, chemical behaviour of films, and the main aspects of packaging design. The chosen citations of food scientific and technical literature give many different examples for causes and cases of food quality changing, their chemical, physical and biological origin and in addition the problematic of shelf-life extension of fresh and processed foods.

Of course the list of citations is not exhaustive but it gives a fundament for systematic and organized research of literature. The computerization of citations would be recommended to improve the expert services of TPC.

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ANNEX 13

LIST OF CONTACTS

United Nations Industrial Development Organization, Bangkok	Mr. Nils Ramm-Ericson Country Director Mr. Johan Nelis Programme Officer
Thailand Institute of Scientific and Technological Research	Mr. Santhad Rojanasoonthon Governor
Thai Packaging Centre	Ms. Amornrat Swatditat Director, National Project Co-ordinator
President Interfood Co.Ltd.	Mr. Suchai Ratanajiajaroen Vice President Mr. Krid Siraprapasiri Managing Director
South East Paper Industry Co.Ltd.	Mr. Viroon Cunhakittinant Managing Director Mr. Boonmee Lertviriyavanich Sales and Office Manager Mr. Somkid Visesmit Factory Manager
Thai Offset	Mr. Suthee Limatibul Deputy General Manager
Strongpack Co.Ltd.	Mr. Sophon Sariwatta Marketing Manager
Sky Fresh Co.Ltd.	Ms. Pisana Puechpol Managing Director

Thai Cargo Department	Mr. Gavin Ussavashutroj Director
Chisso Engineering Co.Ltd.	Mr. Hisaaki Kawahara Deputy General Manager
Ipeco Co.Ltd.	Mr. Wilhelm Mayer Director

Comments

1. The first recommendation of the expert concerns acquisition of a Gas-Chromatograph and a High-Performance-Liquid-Chromatograph. The fact that acquisition of the first one of these instruments, namely the Gas-Chromatograph, had been also recommended by the expert in plastic films and laminates, must be particularly stressed. The coincidence of the same recommendation shows the importance which this item of equipment would have for the Thai Packaging Centre. Therefore, the backstopping officer strongly recommends that actual acquisition of the Gas-Chromatograph be seriously considered by the national authorities concerned.

2. Similar coincidence of recommendation concerns strengthening of the Thai Packaging Centre liaisons with packaging manufacturer and user industries. This recommendation, in fact, is applicable to most technological institutions in developing countries, working in the packaging sector. Actual utilization of institutional capability of technical support to the industries concerned, will increase through these liaisons and promotion of an active co-operation. The information service of the Centre should actually establish a permanent two-way system of communication with the industries, which would lead to their progressive acquaintance with the technical support which they can receive from this specialized institution.

3. The report includes many annexes. Some of them are of a volume which could appear excessive. However, taking into consideration the high degree of this mission's specialization and the advantages of the existence of a reference document on shelf-life analysis at the Thai Packaging Centre, all the annexes proposed by the expert are actually attached for guidance of the mission counterparts on their future related work.