HORTIN II Co Innovation Programme

Towards cost effective, high quality value chains

Rambutan processing and packing

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The purpose of the HORTIN II programme is to contribute to the development of cost effective high quality value chains for vegetables and fruits. Among others this can be achieved when technology development takes place in close collaboration between public institutions, farmers and private companies.

In Indonesia, the programme is carried out by the Indonesian Vegetable Research Institute (**IVEGRI**) in Lembang and the Indonesian Centre for Agricultural Postharvest Research and Development (**ICAPRD**) in Bogor. In the Netherlands Applied Plant Research (**APR**), WUR-Greenhouse Horticulture (**GH**), the Agricultural Economics Research Institute (**AEI**) and the Agrotechnology and Food Science Group (**AFSG**), all part of Wageningen University and Research Centre, are the principal partners.

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CONTENTS

Executive summary

Rambutan is a tropical fruit appreciated by Indonesian consumers and by European consumers. Rambutan is a non-climacteric fruit, which must be harvested when it has reached an optimal eating quality and visual appearance, since it will not continue to ripen once removed from the tree. Once harvested, quality decays are initialized. These decays can be slowed down by conditioning correctly the fruit from producer to consumer areas or by can be processed with different technologies to extend shelf life.

An overview has been presented of a whole range of processing technologies that can be applied to extend the shelf life and quality of rambutan. All technologies reported have been evaluated based on their effect on quality, appearance and costs (table 1, chapter 4). Not all technologies are feasible to implement on the Indonesian market, due to regulations and high investments for novel processing. However, juice processing and preservation seem promising.

It has been established that several packages and concepts permit to extend significantly the shelf life of fresh Rambutan fruits. The majority of them are actually or on the market or easily applicable. Modified atmosphere packaging is suitable to extend shelf life of rambutan in two ways. Firstly, it helps to reduce or prevent browning by maintaining a higher relative humidity around fruits inside the sealed film, which prevents water loss due to transpirations. Secondly, modified atmosphere packaging prevents cross contamination during transportation and storage. However it is important to check the feasibility of implementing these concepts to the specific Indonesian Rambutan production. Recommendations are made specifically for the local and export market.

1. Introduction

Rambutan is a tropical fruit appreciated by Indonesian consumers and by European consumers. Indonesia produces each year an average of 350000MT of Rambutan that is essentially destined for local market (Poerwanto 2005). The exportation of Rambutan produced by Indonesian farmers is localized to United Arab Emirate, Europe and lands in neighbour of Indonesia. Whereas the export distribution appears large, the total quantity of export is limited by transport conditions and the short shelf life of product.

Under normal atmosphere conditions, the expected shelf life of Rambutan doesn't exceed one week (cultivar dependant). Studies about extension of shelf life of Rambutan produced in tropical countries have shown a possible extension until 20 days. To reach this additional shelf life, particular cares and packaging/storage materials should be implemented. The present review describes first the rambutan production in Indonesia and the limiting factors met in the distribution of the product. A resume of the researches led in the optic to extend shelf life of Rambutan fruit by modified atmosphere packaging or others handling is drawn up. Finally each possible option is developed to adapt it to the actual Indonesian conditions.

Rambutan is a tropical fruit that grows in the majority of the western Indonesian islands between 0 and 600 meters above see level. Indonesian Rambutan production amounts to 3.5% of total fruit production. Despite of the important demand of consumer, distribution is limited by the short shelf life of the fruits after harvesting. Rambutan is a non-climacteric fruit, which must be harvested when it has reached an optimal eating quality and visual appearance, since it will not continue to ripen once removed from the tree. Rambutan is of acceptable appearance between 16 and 28 days after colour-break when the skin and spinterns (hair-like protuberances) are brightest and most evenly coloured (Wanichkul and Kosiyachinda, 1982). When rambutan is harvested too early, acidity and a lack of sweetness arise, while fruit harvested too late can be bland. Once harvested, quality decays are initialized. These decays can be slowed down by conditioning correctly the fruit from producer to consumer areas or by can be processed with different technologies to extend shelf life. Maturity of fruit is determined according to several criteria (Ketsa and Paull) :

- size of fruit
- skin and spintern coloration
- sugar and acid content

As the majority of tropical fruit, Rambutan is sensible to chilling injury during storage. Depending to the cultivars, the fruits can be stored at 10°C minimum. The main chilling injury is the development of brown coloration on the skin and spintern. This decay reduces the shelf life of the fruit, as the consumer judges brown fruit not acceptable (O'Hare et al. 1994). However chilling injury doesn't affect the taste of the fruit. Storage at local room temperature induces higher respiration rate of the fruit. Enzymatic reaction and dehydration of the fruit are speed up under this storage conditions and short shelf life of approximately 4 to 6 days is the result. Development of off-taste and browning of Rambutan skin are the main quality decays observed during storage at high temperature (>25°C). Due to climatic condition of Indonesia and the lack of cooling equipments, the shelf life of Rambutan normally handled is similar to the short shelf life described previously.

2. Processing possibilities for rambutan

As discussed in the previous chapter, the deterioration of rambutan starts directly after harvesting, so it is important to start directly with proper handling techniques to extend shelf life. Important quality parameters during the storage of rambutan are skin and spinterns colour of the fruit, flavour, moisture level, injuries, level of titratable acid, level of total soluble solids, and level of pathogens. In this chapter, a number of processing technologies are described to extend shelf life, and their suitability for application on rambutans. An overview can be found in Table 1, chapter 4.

2.1. Curing

Method
Curing is one of the oldest forms of food preservation. Curing involves adding some combination of salt, sugar, spices, vinegar, or sodium nitrite to animal foods. Smoking, a flavouring technique and preservation method, is another ancient technique that is commonly used with curing.

Description of technology
Curing and smoking preserve food by binding of removing water, so that it is not available for the growth of micro organisms. These methods impart a distinctive colour and flavour to food and sometimes eliminate the need for refrigeration. Curing is associated with cancer-causing nitrosamines by the reaction with other chemicals and with hypertension, due to its very high sodium level.

Suitability for rambutan
Curing is not suitable for rambutan, due to its specific flavours which are produced.

2.2. Drying

Method
Three basic methods of drying are used nowadays: Sun drying, a traditional method in which foods dry naturally in the sun; hot air drying, in which foods are exposed to a blast of hot air; and freeze-drying, in which a frozen food is placed in a vacuum chamber to draw out the water.

Description of technology
Removing the water preserves food, because micro organisms need water to grow and food enzymes cannot work without a watery environment. Removing the water also decreases the weight and volume of foods, thereby reducing transportation and storage costs.

Suitability for rambutan
Drying is a suitable processing technology for rambutan. However, the fruit has not the same conditions as when it is just harvested; the dried product remains in good physical and chemical conditions for 5 months at room temperature when the product is pre-treated by soaking rambutan fruit in a 40°Brix sugar syrup for 3 days before the fruit is dried to a moisture content of 19% (Food Technology Digest, 1986).

2.3. Canning

Method
Canning is used to preserve a wide variety of foods, including soups, sauces, fruits, vegetables, juices, meats, fish and some dairy products. Canning preserves food by heating it in airtight, vacuum-sealed containers.

Description of technology
The can is filled with food, and air is pumped out of the space remaining at the top of the can to form a vacuum. The container is sealed, heated in a cooker (called retort), and than cooled to prevent overcooking of the food inside. The process removes oxygen, destroys enzymes involved in food spoilage, and kills most micro organisms that may be present in the food. Canned foods are popular, because they are already partially prepared and cooked, can be stored without refrigeration for long periods, and are generally low in costs. However, because of the high temperatures required for sterilization, canning affects the colour, texture, flavour, and nutrient content of foods. Fat-soluble vitamins and minerals are barely affected by heating processing, but water-soluble vitamins can leach into canning or cooking water that may later be thrown away during preparation.

Suitability for rambutan
Canning is a well-established conservation method for rambutan in Malaysia and Thailand. Research of Ortiz and Cordero (1984) showed that peeled fruits which were canned in syrup and stored at room temperature for 9 months retained a good appearance with a very satisfactory taste. Fruits which were most suitable for canning were those which were harvested when yellow, approximately 15 days before the harvest date for fresh consumption. Despite of the good appearance and taste, the nutritive value of rambutan is decreased due to the high processing temperatures.

2.4. Addition of chemical additives

Method
Food additives are chemicals that are added to food in small amounts. Direct additives are added consciously during processing to make food look and taste better, maintain or improve nutritive value, maintain freshness, and help in processing or preparation. Some additives help preservation of food by preventing or slowing chemical changes and the growth of micro organisms in food. One can think about sulphite agents, like sulphur dioxide and potassium metabisulphite.

Description of technology
Sulphur dioxide and sulphite are used to inhibit microbial growth but also as bleaching agent or antioxidant. Sulphite can react with different food components lowering the effective concentration. Microbial inhibition is strongest at low pH values.

Suitability for rambutan
The use of sulphating agents on fresh products was restricted in the USA, and the use of sulphites on fruits and vegetables that are to be served raw, or presented as fresh to the public was prohibited (FDA, 1986), so it can not be used in rambutan.

2.5. Low temperatures

Method
Storage at temperatures just above or below 0°C, (deep) freezing, cold storage, super chilling, mild chilling

Description of technology
Storage at low temperature slows many of the enzymatic reactions involved in spoilage and reduces the growth rate of micro organisms (though it does not kill them). To minimize microbial growth, refrigerators should be kept at 0°C to 4°C and freezers at or below 0°C. Refrigeration is advantageous, since it does not cause chemical or physical changes to food. Freezing allows foods to be stored for longer periods than refrigeration, because it inhibits enzyme activity and microbial growth to a greater degree. The greatest disadvantage of freezing is that the water in food expands and forms ice crystals. The ice crystal formation disrupts the structure of plant and animal cells, giving frozen food a softer texture after thawing. Newer technologies like faster freezing result in less damage to cells.

Suitable for rambutan
This method is not suitable for rambutan, since rambutan shows chilling injury when it is stored at low refrigerator temperatures, whereby small changes occur depending on the cultivar. Chilling injury occurs at temperatures below 5°C, leading to physiological damage of the skin and spinterns (softening and colour change), reducing edibility of the fruit and production of an off-flavour of pulp (Kondo, 2007). Storage at a temperature around 10°C is the best temperature to store rambutan without changing any properties (Landrigan et al., 1998).

2.6. Controlled atmosphere packaging

Method
Controlled atmosphere packaging maintains a defined mix of gases over time by some external apparatus or internal chemical reactions. Controlled atmosphere packaging is often used in sealed warehouses where temperature and humidity are closely controlled, whereby the composition of gases in the atmosphere is altered to minimize spoilage. In ripening rooms the control of atmosphere is also an important issue.

Description of technology
Gas atmosphere in a package can be controlled mechanical by measuring the container atmosphere and adjusting the gas levels to maintain a predetermined mixture of $CO2$, $O2$ and $N2$. Another method to control the atmosphere in a package is by placing an oxygen absorbing sachet inside a barrier package, using a chemical reaction. The sachet absorbs any oxygen that transmits through the package barrier.

Suitable for rambutan
Controlled atmosphere storage can extend the shelf life of rambutan for three weeks, when proper controlled atmosphere conditions are chosen (Ponrot et al. 2006). In chapter 3 the use of controlled atmosphere packaging will be further discussed.

2.7. Modified atmosphere packaging

Method
Modified atmosphere packaging can retard microbial spoilage and slow down the browning and water loss, by modification of the gas atmosphere in a package.

Description of technology
Gas atmosphere in a package is modified by direct injection of gasses into a package (often $CO2$ or $N2$), evacuating air from the package, or interaction between package contents and the air in the package causing the package atmosphere to modify over time. The latter is what happens with fresh fruit and vegetables; with proper packaging, the natural respiration of a product causes $O2$ levels to drop and $CO2$ levels to rise. So, the atmosphere inside a package is modified but not controlled. Oxygen depletion and/or $CO2$ addition into a package are effective in retarding the growth of the typical aerobic spoilage bacteria in muscle foods.

- $CO2$: causes a decrease in growth rate and delay of spoilage by extension of the lag phase and generation time. $CO2$ is more effective at low temperatures. It's mechanism of action is not fully understood.
- $O2$: Causes an increase in colour and odour shelf life,
- $N2$: is used to balance the gas composition

Modified atmosphere packaging has the advantage of low cost and easy implementation at the commercial level.

Suitable for rambutan
Modified atmosphere packaging is suitable to extend shelf life of rambutan in two ways. Firstly, it helps to reduce or prevent browning by maintaining a higher RH around fruits inside the sealed film, which prevents water loss due to transpirations. Secondly, MAP prevents cross contamination during transportation and storage. To extend shelf life of rambutan, it is recommended to manage the temperature of the packaged fruit during the whole

marketing chain between 14-15°C, to prevent the negative effect of temperature fluctuations on fruit quality during shipping, handling or at the retail display (Sivakumar and Korsten, 2007). In chapter 3 the use of modified atmosphere packaging will be further discussed.

2.8. Aseptic packaging

Method
Aseptic packaging is now commonly used for packaging milk and juice. Like canning, aseptic packaging involves heat sterilization of food, but unlike canning, the package and food are sterilized separately.

Description of technology
Food can be sterilized more rapidly and at lower temperatures in aseptic packaging than in canning, allowing the food to retain more nutrients and better flavour. Containers are sterilized with hydrogen peroxide rather than with heat, permitting the use of plastic bags and foil-lined cartons, which would be destroyed by heat sterilization. These containers cost less than the metal and glass containers used in canning and also weigh less, reducing transport costs. Aseptically packaged foods will keep without refrigeration for long periods of time, perhaps even years. They are growing in popularity because of their low cost, good taste and nutrition, and convenience.

Suitable for rambutan
Aseptic packaging is a possible processing technique to extend shelf life of rambutan. Nevertheless, heating of the rambutan greatly accelerated unwanted pericarp browning (Follett, 2004). Comparison with canning, a well-established conservation technique used for rambutan, the heating time and intensity are lower for aseptic packaging, implying a reduction in browning using the aseptic packaging technique. So, it can be concluded that aseptic packaging has advantages above canning, although there are better processing techniques to extend shelf life than aseptic packaging.

2.9. Irradiation

Method
Irradiation is a process in which food is passed through a chamber where it is exposed to gamma rays or X rays.

Description of technology
Irradiation kills most bacteria, moulds, and insects that may contaminate food. Irradiation also delays the ripening of fruits and sprouting of vegetables, permitting products to be stored for longer periods of time. Because irradiation involves minimal heating, it has very little effect on the taste, texture, and nutritive value of food. Irradiation with a minimum absorbed dose of 250 Gy is an U.S. Dept. of Agriculture (USDA)-APHIS approved treatment for disinfestations of fruit flies for eight fruits exported from Hawaii, including rambutan (Follett, 2004).

Suitable for rambutan
Irradiation of rambutan at 250 Gy, a minimum dose, has been approved as a quarantine treatment for the export of tropical fruits grown in Hawaii, including rambutan. The effect of irradiation and storage on specific sensory attributes was investigated by Boylston and co-workers (2002). Aroma and flavour tended to be more intense in the irradiated fruit. Firmness decreased as a result of irradiation and storage. The colour of rambutans was significantly affected by irradiation. Irradiation did not contribute to significant changes in the ascorbic acid and carotenoids contents, pH, titratable acidity, and total soluble solids (Boylston et al, 2002; Moy and Wong, 2002). Research of Follett and Sanxter (2000) showed that irradiation has a better maintenance of fruit quality than hot forced air treatment. It is important to keep the local regulations on irradiation of food products and consumer acceptance in mind.

2.10. Fermentation

Method
Today fermented foods are a major sector of the food processing industry. During food fermentations, the controlled action of selected micro-organisms is used to alter the texture of foods, preserve foods by production of acids or alcohol, or to produce subtle flavours and aromas which increase the quality and value of raw materials.

Description of technology
Fermentation is a chemical reaction carried out by many types of microorganisms to obtain energy. In fermentation, micro-organisms break down complex organic compounds into simpler substances. Although chemical changes and microbial growth usually mean food spoilage, in some cases fermentation is desirable and microorganisms are actually added to foods. For example, in the production of beer, wine, and other alcoholic beverages, yeasts convert sugar into ethyl alcohol and carbon dioxide. In the making of yogurt and cheese, bacteria convert lactose, a sugar found in milk, to lactic acid. Alcohol, acids, and other compounds produced in fermentation act as preservatives, inhibiting further microbial growth.

Suitable for rambutan
Overripe or lower quality rambutan can be used for fermentation. Litchi and durian, tropical fruits which are similar to rambutan, could be fermented to wine and juice, and these products are already sold on the East-Asia market. So, fermentation seems to be a very good technique to raise the value of overripe and lower quality rambutan. However, more research should be executed to demonstrate the feasibility of fermentation.

2.11. Pasteurization

Method
Pasteurization is a relatively mild heat treatment, in which food is heated to below 100°C.

Description of technology
Pasteurization is a process which retards microbial growth in foods by heating the food. Unlike sterilization, pasteurization is not intended to kill all pathogenic micro-organisms in the food or liquid. Instead, pasteurization aims to reduce the number of viable pathogens so they are unlikely to cause disease when the product is stored at low temperatures. This heating treatment is less intense than sterilization, keeping a better taste and quality of the product

Suitable for rambutan
Pasteurization gives minimal changes to sensory characteristics and nutritive value of rambutan, whereby the shelf life is extended. Since heat is involved, the firmness of the fruit will be affected, even as the colour of the fruit. However, depending on the purpose of rambutan, pasteurization is suitable to extend the shelf-life.

2.12. Preservation with sugar

Method
Addition of sugar to a product increases the osmotic pressure of the liquid phase at a level which will prevent micro-organism development.

Description of technology
Sugar is used to preserve fruits, either in syrup with fruit such as apples, pears, peaches, apricots, plums or in crystallized form where the preserved material is cooked in sugar to the point of crystallisation and the resultant product is then stored dry. From a practical point of view, it is usual to partially remove water by boiling the product to be preserved, with the objective of obtaining a higher sugar concentration. In concentrations of 60% in the finished products, the sugar generally assures food preservation (FAO, 1995). This method is used for the skins of citrus fruit (candied peel), angelica and ginger. A modification of this process produces glace fruit such as glace cherries where the fruit is preserved in sugar but is then extracted from the syrup and sold, the preservation

being maintained by the sugar content of the fruit and the superficial coating of syrup. The use of sugar is often combined with pasteurization or alcohol for preservation.

Suitable for rambutan
Preservation of rambutan in syrup is an already existing process.

2.13. Jellying

Method
Fruit jelly is based on the high-solids-high-acid principle, with a moderate heat-treatment requirement.

Description of technology
Foods with substantial acidity, when concentrated to 65 percent or more soluble solids, may be preserved by mild heat treatments. High acid content is not a requirement for preserving foods concentrated to over 70 percent solids.
Jellies and other fruit preserves are prepared from fruit by adding sugar and concentrating by evaporation to a point where microbial spoilage cannot occur. The prepared product can be stored without hermetic sealing, although such protection is useful to control mould growth, moisture loss, and oxidation.
The jelly-forming characteristics of fruits and their extracts are due to pectin, a substance present in varying amounts in all fruits. The essential ingredients in a fruit gel are pectin, acid, sugar, and water. Flavouring and colouring agents may be added, and additional pectin and acid may be added to overcome any deficiencies in the fruit itself.

Suitable for rambutan
Rambutan fruit that possesses excellent qualities, and which are visually (un)attractive may be preserved and utilized in the form of concentrates, giving a pleasing taste and substantial nutritive value.

2.14. Wax formulations and edible coatings

Method
Edible coatings on fresh fruit can provide an alternative to modified atmosphere storage through modification and control of the internal atmosphere of the individual fruits.

Description of technology
Wax and sucrose fatty acid esters (SFAE) can be sprayed on fresh fruit to form a layer around the fruit. These coatings slow down the respiratory gas exchange, resulting in a longer shelf life of the fruit. Coated fruit shows decreased water vapour and oxygen transmission, prevents spoilage and retains the fresh-picked quality of tropical fruits (Park, 2003).

Suitable for rambutan
The effect of wax coatings according to weight loss of rambutan is studied. The cultivar ‘R3’ fruits from the Philippines were waxed with prima fresh emulsion and stored at 10°C for 14 days. It was reported that the waxed fruit retain their red colour, while unwaxed fruits turned dull red in colour (Lam and Ng, 1982). Similar observations were reported for cultivar ‘Malwana special selection’ fruits, when the wax Sta-fresh-7005 and Bavistin were applied at 40 ppm (Sivakumar et al., 1998).

2.15. High pressure processing

Method
High pressure processing is a processing technique which destroys micro-organisms by pressure.

Description of technology
High pressure processing is performed in a pressure vessel. The packed food is placed in a pressure fluid that is usually water, or another food safe medium. Additional fluid is pumped into the vessel, resulting in an increase in pressure until the desired operating pressure is reached (100-800 MPa). After a treatment time of 5 to 20 minutes, pressure is decreased and the product has been treated. Products can be pasteurized or sterilized.

Suitable for rambutan
High pressure applications resulting in complete inactivation of vegetative cells may cause a cooked appearance. Therefore, the product can not be sold as fresh. Furthermore, the costs of the equipment and the use of the high pressure processing technology are very high, so it is not suitable for extending the shelf life of rambutan.

2.16. Hot water treatment

Method
Hot water treatment methods have been developed for the control of postharvest diseases in fruits.

Description of technology
The thermal inactivation point for a pathogen is defined as the specific temperature at which inactivation of germination or growth of the propagules occurs. Within a given species, thermal sensitivity varies with age and form of the target fungal structure.

Suitable for rambutan
Hot water treatment at 52°C for 3 min had a marked effect on the colour, cosmetic appearance and eating quality of rambutan. Hot water treatment at 48°C for 1 min helped to retain the colour and eating quality of cultivar ‘Malwana special selection’ fruits at 13°C and 95% relative humidity for up to 14 days (Sivakumar et al., 1998). Hot water treatment at temperatures over 50°C for more than 1 min dipping time resulted in significant weight loss after low temperature storage, and affected the soluble solid concentration and acidity levels in the aril. Furthermore, hot water treatment over 50°C resulted in pericarp browning and showed significant loss of ascorbic acid content in the aril (Sivakumar et al., 1998). Hot water treatment at temperatures over 50°C for longer dipping times caused an increase in polyphenol oxidase activity after treatment, as reported for litchi (Underhill and Critchley, 1993). It is also evident that hot water treatment caused severe spintern and skin browning (Paull et al., 1995). It should be marked that tolerance to high temperatures is cultivar-dependent, because of the different morphological structures in the pericarp and its thickness, as reported with litchi (Wong, 1991). So, hot water treatment can improve the shelf life and fruit quality of rambutan when processing temperature not exceed 50°C and dipping time is not longer than 1 min.

2.17. Processing using ultrasound

Method
Ultrasound waves are used to inactivate micro-organisms

Description of technology
When ultrasonic waves (10-1000 W/cm2) hit the surface of a material, they generate a force. These forces weaken as they move through the food. Ultrasound produces very rapid localized changes in pressure and temperature that cause shear disruption, ‘cavitation’, thinning of cell membranes, localized heating and free radical production, which have a lethal effect on micro-organisms (Fellows, 2000).

Suitable for rambutan
Ultrasound waves are effective in destroying microbial cells, especially when combined with other treatments, including heating, pH modification and chlorination. However, if only ultrasound is used the intensity must be very high, since most micro-organisms and enzymes show a very high resistance to ultrasound. Unfortunately, these

high intensities adversely change the texture and physical properties of the food. So, ultrasound is due to its complex mode of action not the best processing method for rambutan.

2.18. Vacuum frying

Method
Vacuum frying is a processing technique using reduced pressure at frying temperatures to remove water rapidly

Description of the method
Vacuum frying implies rapidly water removing from the surface and inwards under reduced pressure at frying temperatures below the normal atmospheric boiling point of oil, resulting in high quality fried products. Vacuum fried fruit and vegetable chips are crunchy, low in fat and high in fibre content. Furthermore, the natural colour and flavours of the fruit and vegetables are retained with minimal changes.

Suitable for rambutan
Vacuum frying is already used in East-Asia to extend the shelf life of tropical fruits, including rambutan, so it is a suitable conservation method.

3. Packaging possibilities for rambutan

3.1. Introduction

The main problem met with rambutan storage, is the brown coloration of spinterns and skin. This coloration happens principally at the end of the shelf life of the fruits. Browning is the limiting factor in the shelf life. The development of off-flavour and losing texture happen later in time after the discoloration and don't affect the quality of fruit during the actual short period of storage. Browning coloration of fruit is the result of two distinct processes (Landrigan et Al., 1996):

- Due to desiccation of the spinterns and skin that occurs during storage of the fruits. Desiccation is emphasized by storage under dry condition (Relative humidity < 80%).
- A small part of the coloration is attributed to enzymatic activities that occur at the end of the shelf life. The enzymes' activity is accentuated when fruits have been mechanically damaged during harvesting of packing.

3.2. Desiccation

Desiccation of the fruit occurs via the stomata located on the spintern. Under tropical environment, Rambutan trees have evolved to use higher transpiration rate to facilitate transport of nutrients to fruits (Morris and Jobling 2002). The number of stomata on spintern extremity have been increased whereas the stomata on the skin reduced. Ladrigan et al. (1994) has estimated until 50 to 70 stomata per mm² on spintern of Rambutan cv Jit Lee. Additionally to this parameter, the stomata have lost their ability to close during water stress. Standard treatments with abscisic acid doesn't induce any closing of stomata. Due to this physiology disability, Rambutan fruit are extremely sensitive to dehydration especially when fruits are stored at room temperature and low relative humidity.

To assure the longest shelf life, Rambutan fruit should be placed in an environment with a relative humidity of 90-95% (O'Hare, 1995). The high relative humidity reduces significantly the moisture loss of the fruit that results to a slower browning of the fruits spinterns.

In order to assure constant high relative humidity in the surrounding of fruits, several researches have been investigated to determine which packaging concepts are the most convenient. The packaging concepts are extremely varied going from normal punnet to film, hermetic or perforated plastic bag, and expensive concept using moisture absorber (Underhill et Al. 1988)

3.3. Condensation

Regulating the moisture loss by packing Rambutan fruits inside more or less hermetic containers brought about condensation in the surrounding of fruits. This free-water inside packaging reduces significantly the consumer acceptance during purchase act and favours development of diseases and fungi.

Condensation is visible when product inside the package or the complete package have a temperature that differs with one's of environment. To avoid or reduce this problem, it is important to reduce at maximum the temperature variation during storage period and pre-cool the fruit before packing (Landrigan et Al. 1998). The use of appropriated films as antifog film, with perforations or with water absorber (Paterson and Joyce 1994) reduced likewise the total amount of water free in contact with Rambutan.

3.4. Controlled and modified atmosphere

Additionally to the benefit of high relative humidity in the surrounding of the Rambutan during storage, studies have reported a positive effect of high carbon dioxide concentration on the preservation of the pink colour of Rambutan spintern and skin.

O'Hare (1995) claimed that shelf life of Rambutan packing within carbon dioxide atmosphere is extended of 3 to 4 days compared to Rambutan placed under normal atmosphere (with high relative humidity). The effects of oxygen, carbon dioxide and ethylene concentrations were investigated by O'Hare et Al. (1994). A concentration between 9 and 12% of carbon dioxide permits to delay significantly the browning process of Rambutan fruit during the storage period and doesn't stimulate any off flavours development. Effect of low oxygen and ethylene concentrations don't improve the shelf life.

Ratanachinakorn et Al. (2005) have seen some discolorations and eating decays when modified atmosphere packaging was used in extreme conditions. With low oxygen concentration (below 1%) and high carbon dioxide concentration (>20%), development of off-flavour was observed. Skin and spintern browning was as well described when Rambutan fruits are stored under high carbon dioxide concentration (>20%). Despite of the non-effect observed by O'Hare et Al. (1994) of low oxygen concentration on any extensions of the shelf life of Rambutan, Sivakumar and Korsten (2007) have concluded their review by advising to store fruits in atmosphere with 2% oxygen and 5-10% carbon dioxide concentrations (in combination with cooling). Ratanachinakorn et al. recommends controlled atmosphere conditions for rambutan of 7-12% CO_2 with 3-5% O_2 at 10°C (Ratanachinakorn et al., 2005). Since different cultivars response differently to the controlled atmosphere, the optimum conditions have to be established per cultivar.

The combined effect of a package assuring high relative humidity inside the bag, optimal oxygen/carbon dioxide concentrations, cold storage and good handling during harvest/packing moments permits to extend the shelf life of Rambutan fruit from 8 to 20 days (Ponrot et Al. 2006).

Several packaging materials have been investigated to determine the optimal combination between Rambutan cultivar and material properties. Ponrot et Al (2006) have concluded that polyvinylidene chloride (PVDC) and polyvinyl chloride (PVC) films were the most promising to expect a maximum shelf life of 20 days. These films were used to over-wrapped containers destined for exports. Srilaong et Al. (2002) have investigated linear low-density polyethylene (LLDPE) bags with several macro-perforations. Packing Rambutan in bags (1 kg/bag) permits to control the water loss of fruit during the storage period and has a direct positive effect on the colour of Rambutan. The gas concentration inside the LLDPE bag without perforation was still acceptable to maintain high quality Rambutan fruit (7% O_2 and 14% CO_2). A maximum shelf life of 16 days was reached for the bag without perforation whereas the others bags (with perforations) reached a shelf life of 12 days (8 days for storage under normal atmosphere).

O'Hare (1995) concluded his literature review by mentioning the combined effect of modified atmosphere packaging (MAP) with low temperature storage. In order to control the biological activity of fruits inside an isolate environment (package), the products should be stored under conditions that slow down the decay processes. Respiration rate, moisture loss and enzymatic reactions are significantly reduced under low temperature.

4. Discussion and conclusions

4.1. Processing possibilities for rambutan

In this report, an overview has been presented of a whole range of processing technologies that can be applied to extend the shelf life and quality of rambutan. All technologies reported have been evaluated based on their effect on quality, appearance and costs. Table 1 shows an overview of all technologies and their effect on quality, appearance and costs.

Table 1. Overview of processing methods and their effect on quality, appearance and costs

Processing	removes water	pasteurization	sterilization	vegetative cells	enzymes inactivated	micro organisms. inactivated	spores inactivated	modified environment	shelf life extension	product properties affected	costs	suitable for rambutan
Curing	✓					✓	✓	✓	weeks	yes	€	no
Drying	✓			✓	✓	✓			months	yes	€	yes
Canning		✓	✓	✓	✓	✓	✓	✓	months	yes	€	yes
Addition of chemical additives						✓			months ?	possibly	€€	no
Chilling				✓	✓	✓			days	no	€	Yes > 5°C
Freezing				✓	✓	✓			weeks	yes	€	no
Controlled atmosphere packaging				✓	✓			✓	weeks	no	€	yes
Modified atmosphere packaging						✓1)		✓	weeks	no	€	yes
Aseptic packaging			✓	✓	✓	✓	✓		months	yes	€€	yes
Irradiation				✓	?	✓			weeks	yes	€€€	yes; depen-ding on local regulations
Fermentation					✓	✓			months	yes	€€	probably/yes
Pasteurization		✓		✓	✓	✓			weeks	yes	€	yes
Preservation with sugar	✓					✓			weeks	yes	€	yes
Jellying	✓					✓			weeks	yes	€	yes
Wax / coating									days-weeks	no	€€	yes
High pressure processing		✓	✓	✓	✓	✓	✓		weeks-months	yes	€€€	no; too expensive
Hot water treatment									days-weeks	no	€	yes
Processing using ultrasound				✓	✓	✓			weeks	yes	€€€	no
Vacuum frying	✓			✓	✓	✓			months	yes	€€	yes

1) spoilage bacteria

Not all technologies are feasible to implement on the Indonesian market, due to regulations and high investments for novel processing. Since there is a lot of variety in ripeness between the harvested rambutan within each bunch, it is advised to classify the rambutans in three categories; unripe, ripe and overripe rambutan. Each of these categories can be treated with an own processing technology, which gives the easiest handling and best quality products. Unripe rambutan (harvested approximately 15 days too early) can be used for canning, overripe rambutan can be used for fermentation or processing with sugar / yelling due to its flavour and high sugar content, and ripe rambutan can be used for all other processes. Options for juice processing and preservation seem promising and will be studied with in the HORTIN II project.

4.2. Packaging possibilities for rambutan

It has been established that several packages and concepts permit to extend significantly the shelf life of fresh Rambutan fruits. The majority of them are actually or on the market or easily applicable. However it is important to check the feasibility of implementing these concepts to the specific Indonesian Rambutan production.

Good handling of the products is necessary to assure the optimal initial quality and the maximum shelf life of Rambutan. Gentle handling during harvest and transport minimizes mechanical damages and avoids any enzymatic decays of fruits

The production is made at small scale, each farmer has 10 to 20 Rambutan trees and harvests manually the fruits during all the production season. Ones' Rambutans are harvested in bundles; they are transported to local market for direct sell or are set out for exporters. Fruits are not stored under cool conditions if they are destined for the local market. When the fruit will be exported, they must be cool down in the exporter facilities, so few hours after harvesting. In these conditions, applying MAP to control moisture loss and extend the shelf life is challenging. It won't be possible to apply the same technology for both markets. Following recommendations are done specifically to the market goal:

local market:

- As the fruit are stored under "room" temperature, the respiration rate of the product is extremely high and dependant to temperature fluctuations. The use of hermetic bags, that regulates the gas concentration inside them thanks to the natural oxygen consumption and carbon dioxide production, is not applicable. If bags with plastic material as PVC, PVDC or LLDPE are used, these ones should have macro perforations to facilitate the exchange of gas and avoid any high concentration of CO_2. If CO_2 concentration exceeds 20%, development of off-flavours will occur.
- Under this storage condition, it is important to minimize the water loss that happens via the transpiration of the fruits. Storage under high relative humidity (95%) is essential. Perforated bags or carton/paper bags will assure this function and extension of the shelf life will be reached. Carton or paper based packaging can assure a good retention of the free water in the surrounding of the fruits. Furthermore these materials are often cheaper and sustainable.

export market:

- In order to deliver Rambutan fruits to European or Arabic markets, the shelf life of the product should be of 10 days minimum. To reach this recommendation, cooling in association to MAP is required. Knowing the chilling sensitivity of the cultivars cultivated, the lowest temperature should be used to store the fruits. It is also important to cool down the production the faster is possible after harvesting. As explained in the previous paragraph, the local farmers don't own cooling capacities. The transport to exporter location should be done as fast as is possible after harvest. Ones the production arrive to exporter, it should be placed in cooling room. This "treatment" will take place as pre-cooling that will permit to reduce the condensation disagreements that can occur in the packaging.
- The grading/packaging lines are located at the exporter location. The Rambutan fruits are processed and exported directly to consumption countries by plane. Although refrigeration during transport in the plane is not needed, it is important to reduce at maximum the waiting periods before and after fly transport. Cooling should be processed as soon as the products are received by the importer.
- By choosing optimal packaging and controlling at maximum the cold chain, shelf life between 16 and 20 days can be expected. The packaging materials should answer to the following requirements:
    - Relative humidity inside the bag around 95%.
    - Condensation controlled by Antifog material or water free absorber

- o Permeability properties of packaging material should avoid any anaerobic condition and assure a carbon dioxide concentration between 9 and 12%
- o As the packaging facilities at the exporter location are non-existing or extremely limited, the MAP packaging shouldn't require high-tech equipment. The optimum gas concentrations should be reached by the natural respiration rate of the Rambutan fruits.

other options:

- The exporters in Indonesia collect the fruits, grade them and export them by plane unpacked. The importer will collect the product at the airport and process the fruits by packing under MAP.
    - o This option has the advantage to control the chain temperature when the fruit is already packed and reduce the condensation formation inside the bags. Furthermore the investment for packing the Rambutan is lower that ones should be made in Indonesia as the importer can use the packaging line for other product outside the Rambutan season.
    - o The late packaging process induces that the quality of the Rambutan fruit at the packaging moment is lower that if the fruits are packed directly after harvesting. This will permit to reach a shorter shelf life (10 to 15 days) that ones predict for the optimal scenario.
- Another research topic will be to desensitize Rambutan to chilling temperature. By pre-cooling in several phases and in combination with high relative humidity storage, it should be possible to low down the chilling temperature and so extend the shelf life of the fruit. With a shelf life of minimum 3 weeks, transportation with refrigerated sea container is an option (Henry Boerrigter 2008). If this transport can be applied to Rambutan fruit, the total amount of exportation will be increased and the transport cost will be reduced.

5. Literature

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