Natural Rubber : Agromanagement and Crop Processing
Editors : P.J. George and C. Kuruvilla Jacob

Chapter 21

Ribbed sheets

Baby Kuriakose and K.T. Thomas

1. Introduction
2. Processing procedure
   2.1 Standardization of latex
   2.2 Addition of chemicals
      2.2.1 Sodium bisulphite
      2.2.2 Paranitrophenol
   2.3 Coagulation
      2.3.1 Pans and tanks
      2.3.2 Methods
   2.4 Sheeting and dripping
   2.5 Drying
      2.5.1 Smoking and smoke houses
      2.5.2 Solar-cum-smoke drying
      2.5.3 Sun drying
      2.5.4 Air drying
3. Defects
   3.1 Defects of microbial origin
   3.2 Defects due to other reasons
4. Inspection, sorting and grading
5. Upgradation of quality
6. Packing and marketing
7. Power and water requirements
   References

1. INTRODUCTION

Conversion of fresh natural rubber (NR) latex into ribbed smoked sheets is the oldest method of processing. This is widely adopted by rubber growers due to its simplicity, lower cost of processing and the viability even when the quantity of latex is small. Sheet rubber commands a predominant share (74.8% during 1997-98) in the Indian natural rubber market as the proportion of smallholdings in the country is very high.

Raw rubber sheets are of various types like ribbed smoked sheets (RSS), air-dried sheets (ADS) and sun-dried sheets, depending on the method adopted for drying.

2. PROCESSING PROCEDURE

The operations involved in making sheet rubber include sieving, bulking and standardization of latex, addition of chemicals, coagulation, sheeting, dripping and drying. Sieving and bulking operations have already been described.

2.1 Standardization of latex

The bulked latex is to be diluted to a standard dry rubber content (DRC) of 12.5 per cent before it is coagulated. Dilution helps in faster settling of impurities and in obtaining a softer coagulum which can easily be sheeted. It also helps in improving the clarity of the sheets. If dilution is more than the optimum level, the wet sheets become thin and porous and on drying, stretch to irregular shapes. The coagulum from undiluted latex is harder and it contains more proteins and other non-rubber constituents which may appear as 'rust' when the sheet is dried. The quantity of water required for diluting the latex to 12.5 per cent DRC can be calculated using the following equation :

$$\text{Volume of water (L) to be added to field latex} = \frac{D \times V}{12.5} - V$$

where D is the DRC of field latex and V is the volume of latex in L.

Example

Find out the volume of water to be added for diluting 8 L field latex having 37.5 per cent DRC?

$$\text{Volume of water} = \frac{37.5 \times 8}{12.5} - 8 = 16 \text{ L}$$

A quick determination of DRC can be carried out using a metrolac. While diluting latex, the buckets used for carrying the same may be washed with a small quantity of water and added to the latex through sieves. Water used for diluting the latex shall be free from suspended and dissolved impurities.

2.2 Addition of chemicals

2.2.1 Sodium bisulphite

It is usually observed that the surface of latex coagulum from certain clones like RRIM 502 and PR 107 is badly darkened. This phenomenon is called discolouration or surface darkening of the coagulum. Enzymes of the polyphenoloxidase-type catalyse the oxidation of phenols and aminophenols, naturally present in latex, by oxygen from the air to give orthoquinones. Orthoquinones react with amino acids and proteins present in latex to give coloured products resembling melanin (Peries, 1970). Reduced melanin has brown colour while oxidized melanin is black in colour. Addition of sodium bisulphite to latex prevents this discolouration by preferential reaction with oxygen, getting itself converted into sodium bisulphate in the process. The quantity to be used depends on the possible extent of darkening. Usually 1.2 g of sodium bisulphite is sufficient to treat latex containing 1 kg dry rubber. Sodium bisulphite is to be added to the diluted latex as a two per cent solution and mixed uniformly by stirring. Since this chemical decomposes on storage, a fresh solution has to be prepared every day. Use of excess sodium bisulphite may lead to delayed drying of sheets since the excess chemical which remains on the surface of the coagulum gets converted into sodium bisulphate which is hygroscopic in nature. This may favour mould growth on the surface of the dried sheets.

2.2.2 Paranitrophenol

Another chemical which could be added to latex at this stage is paranitrophenol (PNP) which prevents mould growth on the surface of dried sheets. The quantity of PNP required is 0.1 per cent on DRC and it has to be added to latex as a one per cent solution (Barney, 1968). This chemical is toxic and hence its frequent and prolonged contact with skin shall be avoided.

2.3 Coagulation

Coagulation is the process of destabilization of latex by some means for recovering rubber from it. In the case of sheet rubber production, the operation consists of transferring standardized latex into coagulation pans or tanks and adding a suitable coagulant.

2.3.1 Pans and tanks

Standardized latex, after the addition of chemicals, is stirred well and allowed to remain undisturbed in the bulking tank for about 15 to 20 min. It is then transferred to coagulation pans or tanks without disturbing the sediment. Coagulation of the latex may be done in pans, troughs or tanks. Small growers generally use aluminium pans which are of 40 x 30 x 7 cm size. Four litres of standardized latex is taken in each pan so that the sheet prepared weighs approximately 500 g when dried. Troughs used for coagulation, mostly of aluminium, may be of 150.0 x 30.0 x 7.5 cm size. Usually, 20 to 25 L of standardized latex is taken in the trough and coagulated. The coagulation tank is generally 300 cm long, 90 cm wide, 45 cm deep and made of aluminium or brick work/concrete construction lined with porcelain tiles. In this case, a wooden frame at the top helps to insert partition plates 7.5 cm apart. Usually, the coagulation tank is loaded in such a way that the level of latex reaches a height of about 37.5 cm. The slabs of coagulum obtained have a width of 32.5 to 35.0 cm which when sheeted give sheets of 35.0 to 37.5 cm width. The size of the sheets when machined and dried is about 60.0 x 37.5 x 0.3 cm. The capacity of the tanks is in the range of 120 to 135 kg dry rubber.

2.3.2 Methods

There are several methods of coagulation such as coagulation by addition of chemicals, natural coagulation and assisted biological coagulation. In the chemical method, several coagulants such as acids, metallic salts and alcohols are used. Among these, the popular coagulants are acetic and formic acids. In certain cases, sulphuric, sulphamic and phosphoric acids are also used. Dilute acetic and formic acids produce slow and uniform coagulation and excess acid, if any, can easily be removed by washing the coagulum during sheeting or are volatilized during drying. Also, these acids are less dangerous than others for handling. Formic acid is preferred as its action is quick. Moreover, it possesses light antiseptic properties. Acetic acid acts slower and, therefore, may lead to bubble formation in sheets due to bacterial action.

The use of sulphamic acid (catalyst AC) has become popular recently. The dry rubber obtained using sulphamic acid as coagulant has lower viscosity and better colour compared to that obtained using formic acid (Sebastian *et al.*, 1982). However, in some cases, a slight fermentation of latex occurs when this chemical is used for next day sheeting.

Natural coagulation is a result of formation of acids by microorganisms at the expense of non-rubber constituents in latex. Unpreserved field latex coagulates within a few hours of collection but the coagulum is not sufficiently hard to allow processing till about 40 h. The resultant rubber is fast curing and nas a malodour and lower nitrogen content. Natural coagulation is never complete owing to insufficient production of acid from the limited food sources available in latex. Complete coagulation could be accomplished only by increasing the sugar level of latex. Sugar containing materials such as molasses, pineapple waste and coconut water were tried for this purpose. This process is called assisted biological coagulation (ABC). The resulting coagulum is almost comparable in technological properties to those resultant of acid coagulation.

Variation in Mooney viscosity and plasticity retention index (PRI) of rubber obtained using different coagulation methods (Lau Chee Mun, 1980) is given in Table 1.

Table 1. Effect of methods of coagulation on Mooney viscosity and PRI of rubber

Method of coagulation	Moony viscosity*	PRI
Acid	74	96
Natural	92	57
Assisted biological	82	84

* ML (1+4) 100°C

Coagulation of latex by the addition of acid is due to the neutralization of charge on the protective layer of proteins surrounding the rubber particles. The latex proteins which surround the rubber particle and which carry negative charge have an isoelectric point close to 4.7 (Le Bras, 1957). Hence the pH has to be brought to this level for smooth coagulation. For the preparation of sheet rubber, a pH of 4.6 is considered ideal. Dilution of acid is necessary for uniform coagulation of latex and for getting sheets free from air bubbles and stickiness. Acetic acid is to be diluted to one per cent, formic acid to 0.5 per cent and sulphamic acid to five per cent before addition to the latex. Table 2 gives the quantity of different acids required for preparing 1 kg dry rubber.

Table 2. Acid requirement for coagulation of 8 L of standardized latex containing 1 kg dry rubber

Sheeting schedule	Acetic acid	Formic acid	Sulphamic acid
Next day	6 ml in 600 ml of water	3 ml in 600 ml water	
Same day	8 ml in 800 ml of water	4 ml in 800 ml water	10 g dissolved in 200 ml water

The required quantity of dilute acid is added to latex and mixed thoroughly by gentle stirring. The froth formed is then skimmed off with a glass or aluminium (Plate 62. a). If the coagulation is done in tanks, the partition plates are inserted and the tank covered. If the pans are placed one above the other, care shall be taken to keep them flat (Plate 62. b) to avoid uneven thickness of the coagulum leading to non-uniform drying of sheets.

Attempts to use strong acids such as sulphuric acid for coagulating NR latex were made earlier (Wiltshire, 1932). More recent studies have indicated that sulphuric acid can be used as a cheaper coagulant in sheet production, if all the factors such as dilution, washing of wet sheets and machinery are properly taken care of (George *et al.*, 1992; Varghese *et al.*, 1996). It is noticed that 600 ml and 500 ml of 0.5 per cent sulphuric acid solution is sufficient to coagulate standardized latex containing 1 kg dry rubber for the same day and next day sheeting, respectively.

2.4 Sheeting and dripping

After draining out the serum, the coagulum is washed with water before sheeting. The sheeting machinery (Plate 62. c)consists of a pair of plane rollers and another set of grooved ones. The rollers, usually made of cast iron, are of length 60 cm and diameter 15 cm. On the grooved rollers, grooves are cut 3 mm apart, with 3 mm width and depth, at 45° spiral. The design obtained by passing the rolled coagulum through the grooved rollers helps faster drying of the sheets due to increased surface area. It also helps in separating the dried sheets after they are packed in bundles. The nip of the rollers is adjusted in such a way that the sheets will have a final thickness of 2.5 to 3.0 mm after three or four passes through the plane and one through the grooved rollers. For washing, provision is made for continuous flow of water through a line of holes drilled on the lower side of a pipe fitted over the rollers. On the surface of the grooved rollers, a mark can be machined for identification of sheets.

The sheeting battery consists of a set of three or four pairs of plane rollers and a pair of grooved ones (Plate 62. d). The nips of the plane rollers and grooved rollers are set in decreasing order so that after the final pass through the grooved rollers, the thickness of the coagulum is reduced to 2.5 to 3.0 mm. The rollers are driven by an electric motor or a diesel engine.

It is essential that while sheeting, sufficient quantity of water falls over the coagulum to remove serum residues and excess chemicals. If the serum residues are not washed out thoroughly, fungal growth may occur on the sheets. It may also lead to slower drying of the sheets. In cases where paranitrophenol has not been added to the latex to prevent mould growth, the washed sheets are dipped in a 0.1 per cent solution of PNP for about 10 to 15 min. Generally, 10 g of PNP will be sufficient to treat 10 kg dry rubber. The wet sheets are allowed to drip in shade (Plate 62. e) for 1 to 2 h before they are dried.

2.5 Drying

Freshly machined and dripped sheets contain about 20 per cent moisture. For the preparation of RSS, these sheets are dried in smoke houses, while for the production of ADS, smokeless drying chambers are used.

2.5.1 Smoking and smoke houses

Drying of sheets in a smoke house has definite advantages. It is quicker than sun drying and does not cause oxidation by ultraviolet radiation (Thomas, 1971). Inside the smoke house, there is only limited supply of air and it is mostly filled with smoke and carbon dioxide. Hence chances for oxidation of rubber are very limited, provided the temperature is within limits. Also, the creosote present in smoke adheres to the surface of the sheets and prevent mould growth on sheets. The requirements of a good smoke house are (1) minimum drying time, (2) minimum number of defective sheets, (3) easy loading/unloading of sheets, (4) minimum labour requirement, (5) maintenance of temperature in the range of 40 to 60°C, (6) continuous operation, (7) good ventilation, (8) minimum heat loss, (9) maximum fuel efficiency and (10) minimum drying cost.

A smoke house consists of a chamber into which the sheets are loaded either on trolleys carrying reapers or on reapers fitted on a wooden framework. Smoke is generated in the furnace which is usually outside the chamber. Smoke and hot air from the furnace are directed into the chamber through a flue. Air inlets and ventilators are provided at the bottom and top of the chamber respectively. These can be opened or closed for controlling temperature. Temperature can also be regulated by adjusting the rate of burning of the firewood by opening or closing the air inlets in the furnace door. A damper is usually provided at the main flue outlet, as a safety measure to prevent fire entering the chamber in an event of opening the furnace door. The chamber may be of brickwork with a reinforced concrete frame. The smoke house shall be provided with adequate drainage to facilitate removal of serum from the drying chamber. The roof and the false ceiling may be of asbestos sheets and the gap between the roof and the ceiling at the top of the walls shall be closed from all the four sides of the smoke house, so as to avoid heat loss due to air currents over the ceiling and to prevent condensed moisture and carbon from dripping on sheets. Smoke houses are of two types, those in which the furnace is inside the drying chamber and those in which the furnace is outside the chamber.

2.5.1.1 Furnace inside the chamber

Smoke houses of the pit-fired-type and trolley box-type which are used in Sri Lanka come under this. In the pit-fired-type, smoke is generated by burning firewood in a central pit which is inside the smoke house. A thick gauge galvanized iron sheet, slightly larger in size than the mouth of the pit, is fixed 25 cm above so as to spread the smoke. The sheets are hung inside the chamber and a minimum space of 180 cm between the fire and the bottom layer of the sheet is given to avoid over heating of the sheet near the pit. In the trolley box furnace-type, smoke is generated in a fire-trolley on wheels. The advantage of this type of smoke house over the pit-fired-type is that the smoke house can be kept clean since operations such as loading of firewood and removing the ash can be done outside the smoke house.

2.5.1.2 Furnace outside the chamber

There are two types of smoke houses with external furnaces, the ground floor-type and the tunnel-type. In the ground floor-type, the smoke from the furnace is directed to the centre of the smoking chamber. The sheets are hung on reapers fitted to a wooden framework (Plate 63. a). Fresh sheets, after dripping, are put on reapers near the ground and on the next day they are taken from the lower reapers and hung on the upper ones. The usual drying time in this type of smoke house is four to five days. The disadvantages of this type of smoke house are that only batchwise operation is possible and more labour is required, since the sheets are replaced on the reapers every day.

RRIM tunnel-type smoke house meets almost all the requirements of an ideal smoke house. There are four sizes of RRIM tunnel-type smoke houses designated as 1100, 2200, 3300 and 4400 corresponding to the nominal capacity in lb per day. The drying chamber of the 1100-type smoke house has 8 m length, 2.5 m width and 3 m height. A light rail track is laid at the centre of the chamber. The trolleys are accommodated inside the chamber and each trolley carries one day's crop. The floor at the cool end is given a slope of 5 cm from the centre of the rails to the side drains and the side drains are given a slope of 5 cm in 3 m to give rapid elimination of the serum from the drying chamber. The roof and the ceiling are made of asbestos sheets and the gap between the roof and the ceiling is closed. The furnace consists of single brickwork with reinforced concrete top. The furnace arch slopes upwards from the furnace door to the flue outlets. The flue outlets open into the main chamber at various points at the central line of the rail track over which the trolleys carrying the sheets move. Firewood is placed on fire bars arranged at the bottom of the furnace. On the furnace door, there are six ventilation holes, each of 5 cm diameter, at 23 cm height from the floor and 8 slits each 15 cm long and 23 cm away from the neighbouring two sides. The trolleys are made of mild steel angles and are of five-tier construction. Each tier can accommodate 40 reapers. The reapers, having 34 to 35 mm diameter, are placed at a spacing of 75 mm. They are made of either wood or bamboo. Baffles are provided at about 50 mm above the chasis of the trolley to avoid water from the sheets dripping into the flue outlets.

The trolley carrying wet sheets enters the chamber at its cool end and is gradually pushed towards the hotter end as sheets get dried. The ventilators at the top shall be kept open to allow the moist air to escape. The temperature of the smoke house is maintained at 45 to 60°C by adjusting the flue outlets, furnace door apertures, roof ventilators and air inlets on the furnace door. Firewood used for smoking shall be quite dry and in general, 0.5 to 1.0 kg is required to dry wet sheets containing 1 kg dry rubber. The normal drying period is four days. It is better to provide a maximum-minimum thermometer in the smoke house to monitor variation in temperature. Alternatively, a thermometer with recording device kept outside the chamber can also be used.

Readymade, batch-type smoke houses (Plate 63. b) are also available. They are compact in size and are available in different capacities. The materials used in the construction of such smoke houses are either metal or ferro-cement (wire mesh embedded in a cement matrix). The sheets can be inserted into the smoke house from outside. Compared to the conventional smoke houses, these have the additional advantage of movability.

2.5.2 Solar-cum-smoke drying

Drying of sheets in direct sunlight increases the chances of oxidation of sheets, especially when they are exposed to sunlight for longer periods. However, solar energy could be used for drying the sheets by harnessing it using flat plate solar collectors.

In this system, the hot air from the solar collectors is blown into the drying chamber in which the sheets are put on reapers placed on trolleys. The system also contains a furnace for burning firewood which acts as a subsidiary heat source for maintaining the inside temperature during night and also on cloudy days. Reports show that without the subsidiary heat source, it takes about 8 to 12 days for getting the sheets dried but with the back-up heat source using firewood, the drying time could be brought down to five days. Compared to conventional smoke drying, the saving in firewood using the solar-cum-smoke drier is around 60 to 70 per cent. The quality of the sheets produced using this type of drier is comparable to that of sheets prepared by conventional smoke drying (Nair *et al.*, 1988). Although trials have been successfully carried out at RRII using a drier of 600 kg capacity, the high initial investment for the solar heating components is hindering its widespread use.

2.5.3 Sun drying

Growers without smoke house facility dry their sheets in the open sun. It has been reported that sun drying of sheet does not degrade its properties significantly (Tillekeratne *et al.*, 1995). However, it is advisable to limit open sun drying to two days initially followed by smoke drying.

2.5.4 Air drying

The sheets dried in hot air are called air-dried sheets. The chamber is heated by blowing air over a set of electric heaters or radiators to which steam is supplied from a boiler. The temperature inside the drying chamber is controlled thermostatically. The number of heaters required depends on the capacity of the drying chamber. During the first two days of drying, the temperature is limited to 37 to 40°C, as otherwise the sheets may have a darker shade. During the last two days, the temperature is raised to 62 to 65°C. If the design of the chamber is tunnel-type intended for continuous operation, then the temperature at the hot end of the tunnel is maintained at 62.5°C and that at the cool end at 37.5°C.

3. DEFECTS

Defects of one type or other may appear in sheets. These may be either of microbial origin or due to other reasons.

3.1 Defects of microbial origin

Sheets produced under unhygienic conditions or stored in an improper way are prone to defects of microbial origin which include pinhead bubbles, rust, discolouration and mould growth.

3.1.1 Pinhead bubbles

Bubbles of bacterial origin in sheet rubber are like pinheads and in clusters all over the sheets. The presence of gas forming bacteria and acid coagulation above pH 4.8, which favours bacterial multiplication, are responsible for this. Frequent washing of utensils used for handling latex with a dilute solution of formalin or Lysol and addition of sodium sulphite into the latex in the field help to check bacterial growth. Addition of sufficient acid to bring the pH of coagulation below 4.8 is also useful.

3.1.2 Discolouration

The colour change in sheets is due to enzymic action on the non-rubber constituents present in latex and can be controlled using sodium bisulphite.

3.1.3 Rust

Rust is a brownish deposit or more usually a thin invisible film on rubber sheets. This film breaks and becomes visible when the sheet is stretched or scratched. The main reason for the rust formation can be attributed to prolonged dripping of the wet sheet before being introduced into the smoke house. It is caused by yeasts and bacteria. Light-coloured sheets produce rust which is white or slightly yellow. This defect should not be confused with mould growth. Mould, to a large extent, can be removed by brushing but rust remains quite firmly attached to the sheet.

3.1.4 Mould growth

Mould growth on sheets occurs when the moisture content of the latter is high. Usually, when dried sheets are taken out from the smoke house, moisture content is less than 0.5 per cent. Storing the sheets in humid atmosphere or on concrete floor favours mould growth on the sheets. If freshly machined sheets are not washed properly before loading into the smoke house, the non-rubber constituents present in the serum are retained on the surface of the sheets and induce fungal growth. Excessive use of sodium bisulphite results in the formation of hygroscopic sodium bisulphate on the sheet surface. This increases the moisture content and consequent mould growth on the sheet. Sheet rubber exposed to excess smoke produced by a slow burning fire is resistant to fungal attack because of the presence of small quantities of creosote deposited on it during the exposure to smoke (Anandan *et al.*, 1988). However, this effect does not last for more than five to six days. During this period, the fungicidal effect of the constituents of smoke wears off and the sheet becomes susceptible to fungal attack. Relative humidity above 75 per cent and air temperature of 37° to 40°C are favourable for fungal growth. Moisture content of about 0.8 per cent is sufficient for mould growth. The fungi attacking rubber sheets belong to the genera *Aspergillus* and *Penicillium* (Anandan and Loganathan, 1983) Addition of PNP to latex or soaking of sheeted coagulum in PNP solution prevents mould growth.

3.2 Defects due to other reasons

These may arise out of excessive use of certain chemicals, contamination with foreign matter or faulty conditions of drying.

3.2.1 Tackiness

The sheets when rolled and released, shall come to the original form and shall not stick together. Tackiness on sheets may be either due to use of excess sodium bisulphite or coagulant, high temperature during drying, contamination of latex with copper or presence of grease from the bearings of the sheeting machines on the sheets.

3.2.2 Blisters

These are formed on sheet rubber as a result of high temperature in the smoke house. Temperature in the first two compartments where the wet sheets are fed into the smoke house shall be lower than that in the other compartments, preferably in the range of 37 to 40°C. The maximum temperature in the smoke house shall not exceed 60°C. The thickness of the sheets shall be uniform to get sheets free from blisters. Blisters usually appear on the thicker parts of the sheets.

3.2.3 Reaper marks

A slight dark colour along the centre of the sheets is called reaper mark. This is due to the deposit of small carbon particles on that part of the sheet. Reaper marks appear when the sheets are not turned over on the reapers daily. Very thick smoke inside the smoke house enhances formation of reaper marks. Dry firewood shall be used in the furnace and the reapers shall be cleaned occasionally for avoiding reaper marks on the sheets.

3.2.4 Case hardening

The appearance of a white streak in the cut section of a dry sheet is known as case hardening. This is due to any one of the reasons such as rapid drying of the sheets in the early stages, excessive thickness of the sheets and insufficient dilution of the latex which gives a very hard coagulum. Under the above circumstances the surface of the sheets may get dried at a faster rate. The moisture trapped inside does not escape, even if the temperature is increased or the sheets are smoked for longer periods.

3.2.5 Tar drops

On the surface of the sheets, black drops resembling tar may sometimes be seen. This is due to condensation of water vapour on the false ceiling and its dropping on the sheets, carrying carbon deposits along with it. To avoid tar dripping, the space between the ceiling and the roof shall be completely closed, and the ceiling cleaned occasionally.

4. INSPECTION, SORTING AND GRADING

Sheets taken out from the smoke house after drying, are removed from the reapers and visually examined by holding them against clear light to see any speck or impurity remaining inside (Plate 63. c). These are sorted into different grades on the basis of colour, translucency, presence of mould, oxidized spots, blisters, bubbles, dirt, sand and other foreign matter, as per the international standards of quality and packing for natural rubber prepared by the Rubber Manufacturers' Association, New York, as described in the Green Book (IRQPC, 1979). There are six grades of sheet rubber and they are designated as No.1X RSS, No.1 RSS, No.2 RSS, No.3 RSS, No.4 RSS and No.5 RSS.

The relevant parameters for these grades as per the Green Book are given below:

No.1X RSS

The grade must be produced under conditions where all processes are carefully and uniformly controlled. Each bale must be packed free of mould but very slight traces of dry mould on wrappers or bale surfaces adjacent to wrapper found at the time of delivery will not be objected to provided there is no penetration of mould inside the bale.

Oxidized spots or streaks, weak, heated, undercured, oversmoked, opaque and burnt sheets are not permissible.

The rubber must be dry, clean, strong, sound and evenly smoked, and free from blemishes, specks, resinous matter (rust), blisters, sand, dirty packing and any other foreign matter. Small pinhead bubbles, if scattered, will not be objected to.

No master or official international sample has been established for this grade.

No.1 RSS

Each bale must be packed free of mould but very slight traces of dry mould on wrappers or bale surfaces adjacent to wrapper found at the time of delivery will not be objected to provided there is no penetration of mould inside the bale.

Oxidized spots or streaks, weak, heated, undercured, oversmoked, opaque and burnt sheets are not permissible.

The rubber must be dry, clean, strong, sound and free from blemishes, resinous matter (rust), blisters, sand, dirty packing and any other foreign matter, except slight specks as shown in the sample. Small pinhead bubbles, if scattered, will not be objected to.

No.2 RSS

Slight resinous matter (rust) and slight amounts of dry mould on wrappers, bale surfaces and interior sheets, found at the time of delivery will not be objected to. Should 'rust' or 'dry mould' in an appreciable extent appear on more than five per cent of the bales sampled, it shall constitute grounds for objection.

Small bubbles and slight specks of bark to the extent as shown in the sample will not be objected to.

Oxidized spots or streaks, weak, heated, undercured, oversmoked, opaque and burnt sheets are not permissible.

The rubber must be dry, clean, strong, sound and free from blemishes, blisters, sand, dirty packing and all other foreign matter other than specified above as permissible.

No.3 RSS

Slight resinous matter (rust) and slight amount of dry mould on wrappers, bale surfaces and interior sheets, found at the time of delivery will not be objected to. Should 'rust' or 'dry mould' in an appreciable extent appear on more than 10 per cent of the bales sampled, it shall constitute grounds for objection.

Slight blemishes in colour, small bubbles and small specks of bark permissible to the extent shown in the sample.

Oxidized spots or streaks, weak, heated, undercured, oversmoked, opaque and burnt sheets are not permissible.

The rubber must be dry, strong and free from blemishes, blisters, sand, dirty packing and all other foreign matter other than specified above as permissible.

No.4 RSS

Slight resinous matter (rust) and slight amounts of dry mould on wrappers, bale surfaces and interior sheets, found at the time of delivery will not be objected to. Should rust or dry mould in an appreciable extent appear on more than 20 per cent of the bales sampled, it shall constitute grounds for objection.

Medium size bark particles, bubbles, translucent stains, slightly sticky and slightly oversmoked rubber are permissible to the extent shown in the sample.

Oxidized spots or streaks, weak, heated, undercured, oversmoked (in excess of the degree shown in the sample) and burnt sheets are not permissible.

The rubber must be dry, firm and free of blemishes, blisters, sand, dirty packing and all other foreign matter other than specified above as permissible.

No.5 RSS

Slight resinous matter (rust) and slight amounts of dry mould on wrappers, bale surfaces and interior sheets, found at the time of delivery will not be objected to. Should 'rust' or 'dry mould' in an appreciable extent appear on more than 30 per cent of the bales sampled, it shall constitute grounds for objection.

Large bark particles, bubbles and small blisters, stains, oversmoked, slightly sticky rubber, and blemishes of the amount and size shown in the sample are permissible. Slightly undercured rubber is permissible.

Weak, heated, burnt, oxidized spots or streaks are not permissible.

The rubber must be dry, firm, free of blisters, except to the extent shown in the sample. Dirty packing, sand and all other foreign matter other than specified above are not permissible.

5. UPGRADATION OF QUALITY

Sheets of poor quality can be upgraded to a certain extent by subjecting them to the process of soaking in water for a short period followed by cleaning, smoking and clipping. Cleaning can be effected manually or with the help of a rotating brush. The clean sheets are then dried in smoke houses followed by clipping to remove portions undried and contaminated with impurities. This process becomes economically viable when there is a significant price difference between the ungraded sheets and the grades such as No.4 RSS (Kumaran, 1997).

6. PACKING AND MARKETING

Ribbed smoked sheets are packed in rubber-covered bales (Plate 63. d). The maximum weight of each bale shall be 113.5 kg for 0.142 m^3 outside measurements, as per the Green Book. Wrapping of bales may be done on all sides with the same or higher grade of rubber. This type of packing is known as bare back packing. When this is adopted, an outside coating is given with a suitable bale coating solution. This is prepared by admixing a fine variety of talc, kaolin or whiting (calcium carbonate) with a suitably prepared rubber solution. For the preparation of this solution, petroleum solvents like mineral turpentine or kerosene are admixed with rubber in 1:1 ratio and kept overnight. The swollen rubber is then made into a solution by addition of an equal quantity of the same solvent. This solution is stirred well and further diluted to double its volume. Any of the above mentioned powders is then added to this solution so as to get a 25 per cent (w/w) slurry of the powder in rubber solution.

7. POWER AND WATER REQUIREMENTS

Power and water requirements in sheet rubber processing are comparatively low. In factories using hand-driven rollers, there is no requirement of electric power. But water is needed for diluting latex, washing the coagula and for cleaning various utensils used for handling latex as well as the floor of the factory. Approximately 20 to 30 L of water is needed for producing 1 kg dry sheet rubber. In factories where sheeting batteries are used, the electric power requirement depends on the size of the battery. For smaller units, 2.24 kW (3 hp) motors are adequate. For larger ones, 3.73 to 5.6 kW (5.0 - 7.5 hp) motors are used. The water requirement is same as mentioned earlier. For effective operation of solar-cum-smoke dryers, a blower is essential to propel the air into the drying chamber. A 600 kg capacity solar-cum-smoke dryer requires 0.74 kW (1 hp) motor for this purpose.

REFERENCES

Anandan, C.R. and Loganathan, K.S. (1983). Methods to inhibit mould growth in sheet rubber. *Proceedings, IRMRA 12th Rubber Conference*, pp. 67-73.

Anandan, C.R., Jayaram, V.S. and Loganathan, K.S. (1988). Gas fuelled dryer for drying natural rubber sheets. *Proceedings, Fourteenth Rubber Conference*, Indian Rubber Manufacturers Association, Bangalore, India, 1988, pp. 51-57.

Barney, J.A. (1968). Processing of natural rubber: Information on current practices. *Rubber Research Institute of Malaya, Planting Manual*, **13** : 32.

George, K.M., Varghese, L. and Mathew, N.M. (1992). Use of sulphuric acid as coagulant for natural rubber latex. *Journal of Plantation Crops*, **20**(Supplement) : 336-341.

IRQPC (1979). *International standards of quality and packing for natural rubber grades, The Green Book.* International Rubber Quality and Packing Conferences, The Rubber Manufacturers Association Inc., Washington D.C., 19 p.

Kumaran, M.G. (1997). Developments in production, processing, quality control and effluent treatment of natural rubber in Indonesia, Malaysia and Thailand. Report on the Technical Mission, Rubber Board, Kottayam, 103 p.

Lau Chee Mun (1980). Basic factors affecting SMR technical properties. In : *RRIM Training Manual on Natural Rubber Processing*. Rubber Research Institute of Malaysia, Kuala Lumpur, pp. 28-32.

Le Bras, J. (1957). Rubber : Fundamentals of its science and technology. Chemical Publishing Company, New York, p. 72.

Nair, N.R., Thomas, K.T., Varghese, L. and Mathew, N.M. (1988). Solar-cum-smoke drier for raw sheet rubber. *Indian Journal of Natural Rubber Research*, **1**(2) : 13-21.

Peries, O.S. (1970). A handbook of rubber culture and processing. Rubber Research Institute of Ceylon, Agalawatta, 188 p.

Sebastian, M.S., Balan, M.V. and Thomas, E.V. (1982). A new coagulant for natural rubber latex. *Proceedings of the Fifth Annual Symposium on Plantation Crops*, 1982, Kasaragod, India, pp. 316-323.

Thomas, E.V. (1971). Effect of sun drying of sheet rubber and studies on sun-dried sheets prepared with antioxidants. *Proceedings of the Fifth Technical Seminar of Indian Rubber Manufacturers' Association*, 1971, Bombay, India, pp. 265-271.

Tillekeratne, L.M.K., Nugawela, A., Jayasuriya, M., Weeraman, S. and Siriwardena, T.A.S. (1995). Utilisation of sunlight for drying of rubber. *Journal of Natural Rubber Research*, **10**(2) : 77-81.

Varghese, L., George, K.M. and Mathew, N.M. (1996). Use of sulphuric acid as coagulant for natural rubber latex : Long term effects on rubber and machinery. *Indian Journal of Natural Rubber Research*, **9**(1) : 22-27.

Wiltshire, J.L. (1932). Sulphuric acid as a latex coagulant. *Journal of the Rubber Research Institute of Malaya*, **4**(2) : 94-103.