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AN IMPROVED METHOD OF ROLLING OF SHEET RUBBER

Vinoth Thomas

Rubber Research Institute of India, Rubber Board, Kottayam-686 009, Kerala, India

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An experiment was conducted in four Group Processing Centers (GPCs) attached to Rubber Producer's Societies (RPSs) with additional rolling of wet ribbed sheet through a conventional 1) plain, 2) ribbed and 3) a specifically fabricated 'twin roller' (comprising of an upper plain and a lower grooved one), using the sheet batterry. Additional rolling using twin roller led to a reduction in thickness (34%) and an increase in effective surface (3-15%). This led to faster drying of sheets, thereby saving the drying time by 25 per cent. Comparable results were obtained by additional rolling using a normal grooved roller that can be easily adobted by the small growers. The present innovation resulted in saving firewood and using smoke house space effictively even as quality of the sheet produced was good.

Key words : GPCs, Quick smoke drying, RSS 1, Sheet rubber, Thinning, Twin roller

INTRODUCTION

Proper and quicker drying of sheets is important in the processing of natural rubber latex as ribbed smoked sheets (RSS). Of the more than one million rubber growers in India, more than 70 per cent prefers to process latex obtained from the field into sheet rubber (Thomas, 2011). The price of sheet rubber fluctuates quite often, and therefore, growers are tempted to store the sheets to sell at the right time. Driven by industry demand, majority of small growers produce RSS 4 or lower grade sheet in their own house hold (Kuriakose, 1992) whereas Group Processing Centers (GPCs) working under the Rubber Producers Society (RPS) collect latex from their members to produce superior quality RSS 1 or RSS 2 grade sheet which fetch a higher price.

The steps involved in sheeting of the latex coagulum and smoke drying are important in the production of good quality sheet rubber within a reasonable time. The thickness, serum content in the wet sheet and retention of effective surface area are important factors affecting sheet drying. Conventionally, sheet rubber is prepared by rolling the latex coagulum through a set of plain roller followed by grooved roller for squeezing out water and increasing the surface area for facilitating fast drying (Morris, 1989; Mathew, 2001). After completing the dripping process, the wet sheet will be loaded in smoke house and it takes four days to get RSS 1 grade sheets in the GPCs. Not much of research has gone into shortening the duration of drying without compromising sheets quality. A quick and easy method for effective drying of sheet rubber ensuring better quality has been attempted which involves thinning, increasing the surface area and reducing the

Correspondence: Vinoth Thomas (Email: vt@rubberboard.org.in)

serum content by providing additional rolling of wet sheet. The advantages of this system over conventional practice are discussed.

MATERIALS AND METHODS

Coagulation of fresh latex, as is practiced widely in sheet rubber production, is in fact a gelation process. After addition of acid, the entire latex, over a period of a few hours, gets solidified into a single mass or gel. The water content of the gel at this stage is normally in the range of 85 per cent. On keeping, the gel slowly exudes water and by next morning the solid mass of coagulum normally floats in the serum. At this stage the water content of the coagulum could be anywhere between 60 and 70 per cent. Rolling is done to squeeze the coagulum and thus to drive out as much water as possible and to prepare the coagulum into a thin sheet. For this the coagulum is passed thrice through a pan of plain rollers with progressively reduced nip settings and finally once through the grooved rollers.

For further thinning and increasing the dimensions and surface area of the wet sheet an experiment was conducted in three GPCs in Kerala state *viz.* Thalakkod (Ernakulam Dist.), Thiruvilluamala (Thrissur Dist.) and Manimooly (Malappuram Dist.) during the pre- monsoon period in 2015. These GPCs' use sheeting battery fitted with three plain rollers followed by one grooved roller each with a diameter of 12.5 cm for rolling latex coagulam. At each location, the treatments with batches of 50 pieces of latex coagula of the previous day were subjected to rolling by passing through the sheeting battery, and then provided additional rolling of wet ribbed sheet either through a plain, ribbed or a specifically fabricated 'twin roller' as detailed in Table 1. A twin roller set comprising of an upper plain and a lower grooved rollers with the same diameter of 12.5 cm, was fabricated specifically for the study (Fig.1a). Additional one or two passes either through the plain, grooved or twin rollers was taken up using individual motorized conventional rollers powered with a motor (0.5HP; 1250 RPM). After completing the rolling as depicted in Table 1, sheets were hung for three to four hours for dripping in two of the GPCs, while the wet sheets were stacked for a few hours in Thiruvilluamala GPC before loading in the smoke house for drying. These sheets were turned upside down the next day afternoon for proper drying and to avoid reaper mark. Thickness dimensions and weight of the sheet before and after drying,

Table 1. **Type of rollers used and additional rolling provided to the wet sheet**

Treatment	Type of roller	No. of additional rolling	Total no. of rolling given to the sheet
T1	Plain	One	5
T2	Plain & grooved	Two (one each)	6
T3	Grooved	One	5
T4	Grooved	Two	6
T5	Twin roller	One	5
T6 (Control)	(Sheeting battery with 3 sets of plain rollers and 1 set of grooved roller)	No additional rolling	4

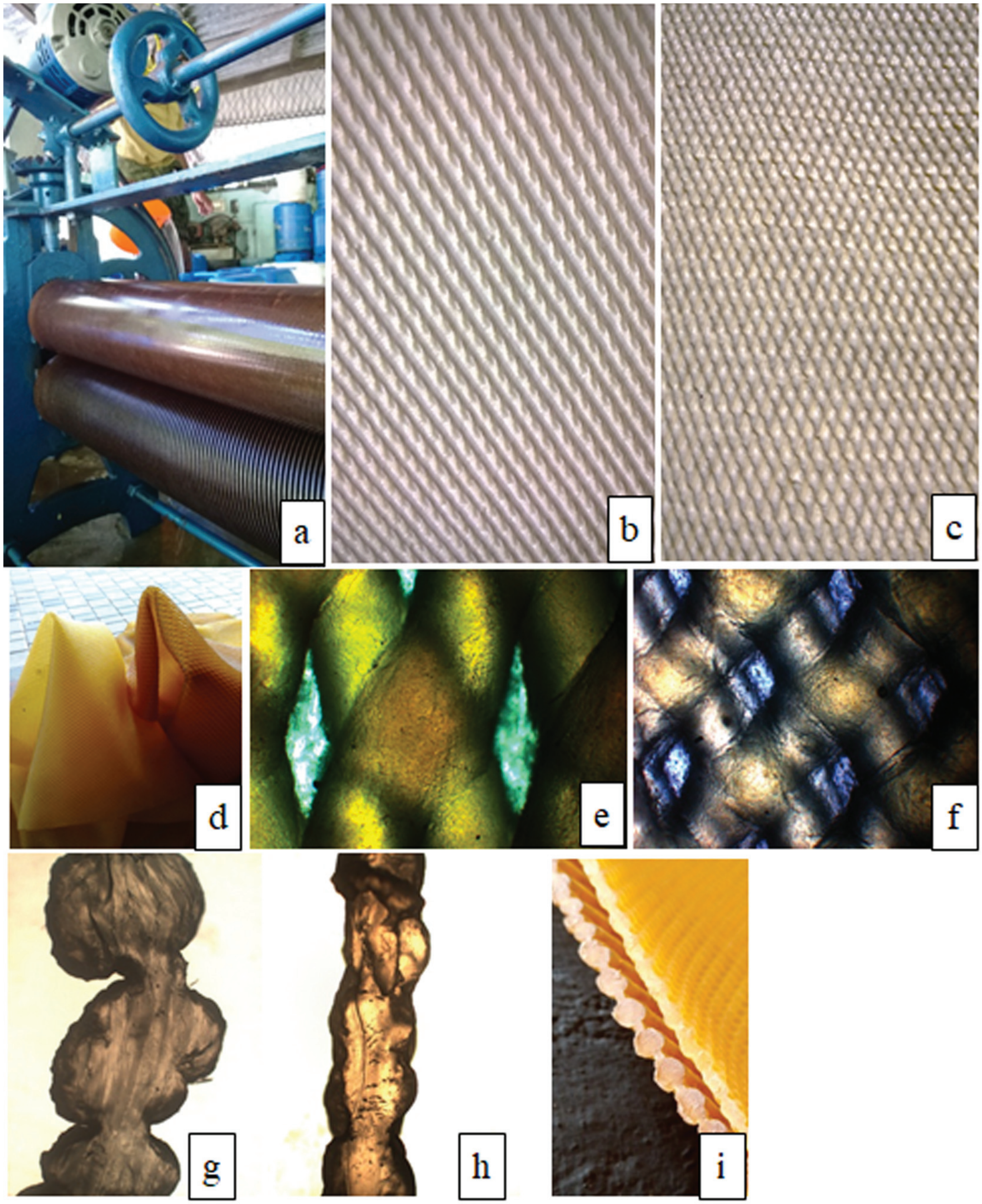

Fig. 1. (a-i) a. A twin roller set comprising of an upper plain and a lower grooved rollers with the same diameter b. and c. Surface pattern of sheet for control and after twin rolling. d. Sheet colour after smoke drying: ideal colour for twin rolled one while the control sheet deposited excess smoke. e. and f. Surface sculpture of conventional and twin rolled sheet after drying. Note the encircled region for thick deposition of material. X6. g. Cross sectional view of dry sheet under microscope (6X). h. Thick control sheet and i. thin experimental sheet.

quantity of water squeezed out after additional rolling, and time taken for drying of sheet were recorded. After drying, experimental sheets were taken out from the smoke house and graded by experts from rubber trading companies.

Revalidation of the data was done at the GPC, Poothrikka (Ernakulam Dist.) equipped with sheeting battery having four (old type) and five (new type) sets of rollers (in which the fourth and fifth rollers respectively were grooved. Morphology of the sheet was studied using Leitz Diaplan microscope equipped with a Leica DFC 320 camera and Qwin Image analyser.

RESULTS AND DISCUSSION

Sheet making

It is well known that thinning, increasing the surface area and reducing the serum content of latex coagulum by passing it through rollers facilitate fast and efficient drying of sheet rubber. In GPCs, latex coagulum of the previous day is made into sheet rubber by passing through the sheeting battery comprising of three sets of plain rollers followed by a set of grooved rollers. Immediately after passing through the sheeting battery, a wet ribbed sheet under experimentation weighed above 854g on an average, which contains both rubber and serum, and it is a diphasic medium during drying (Auria *et al*., 1991). Further squeezing of the remaining water from these sheets (96-164 ml) was achieved by providing an immediate additional rolling, either through the conventional plain or grooved rollers or by using the new twin roller. The highest quantity of water was squeezed out when the sheet was rolled additionally through the plain and then with grooved rollers (T2-164 ml), followed by two pass through the grooved one (T4-152 ml); a single pass through the twin roller (T5-130 ml); one pass through plain (T1-96 ml) and one through grooved roller (T3-96 ml).

A fresh wet sheet measures an average length of 70 cm and breadth of 40 cm, which may vary to an extent of about two per cent mainly due to the difference in the DRC of latex collected from various fields. After providing extra single or double passes through plain and/or ribbed rollers, apart from squeezing out of excess serum, the dimensional area of wet sheet was increased by 3.4 to 4.7 per cent (Fig. 2). Single pass through the twin roller recorded the highest area increment (14.8%). Once the interlocking gets imprinted in the sheet with the cris-crossing of ribbed rollers of the sheeting battery, further dimensional increment through subsequent rolling can be made only to a limited extent.

The advantage of a twin roller is accomplished through differential speed on either side of the sheet and thereby generating friction within the sheeted coagulum, which cannot be achieved using conventional ones having identical pair of rollers. The stretching effect thus created upon the sheet and enabling increasing the dimensions, thinning and squeezing out more serum. Increase in dimensional area of sheets following additional pass did not make any difficulty to accommodate them in the existing wooden reapers used for hanging them in the smoke house. Differential displacement is experienced on either sides of the sheet with twin roller having a pair of rollers of same diameter, and without providing an additional gear system which enhances the future scope of the present method in rubber sheet making.

Drying by syneresis

The sheeted coagulum is then allowed to drip off water exuding due to syneresis-expulsion of serum from the latex coagulum by contraction of the structure of rubber

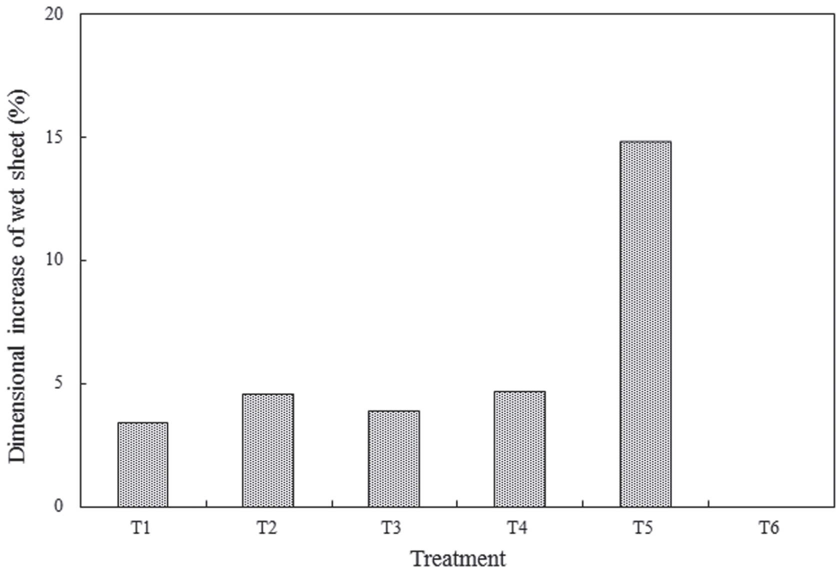

Fig. 2. Dimensional increase to the wet sheet (%) companed to control (T6)

particles (RAPRA, 2002), before it is fed into the smoke house. Dripping from the experimental sheets was over in 20-30 minutes, whereas the control sheet took three to four hours. In Manimooly and Thalakkod GPCs, immediately after rolling the sheets were hung under shade for dripping excess serum before loading into the smoke house. At Thiruvilluamala, they are forced to stack the wet sheet for four to five hours with the available minimum infrastructure and labour utilisation. Separating these stacked wet sheet for loading into the smoke house was time consuming, difficult and an average of two per cent of the sheets were left un-separated. Additional rolling can solve the above difficulty to a great extent as the stickiness was comparatively low for the sheet. This observation is in agreement with the earlier reports that the imprints on the sheet are to increase the surface area and to reduce the tendency for sheets to stick together (White, 1995; Indian Rubber Institute, 1998).

The rate of syneresis decreases with time and when it falls below the rate of evaporation, dripping ceases (Edgar, 1958). At Manimooly GPC, wet sheets after dripping were loaded in racks in the smoke house. The control sheets showed further dripping due to syneresis when the temperature increases in the smoke house as reported by Morris (1989). It is inferred that external factors particularly gradual increment in temperature have a role in syneresis and expel a reasonably good amount of serum within a limited time. Dripping inside the smoke house was not observed for the sheets passed through the twin rollers. This needs further investigations as the thickness of sheet, temperature, air circulation and humidity inside the smoke house are crucial factors in drying process of the sheet (Edgar, 1958; Iyer, 2013), particularly during the monsoon and post-monsoon periods.

Smoke drying

The practices followed for sheet making and time taken for smoke drying vary in

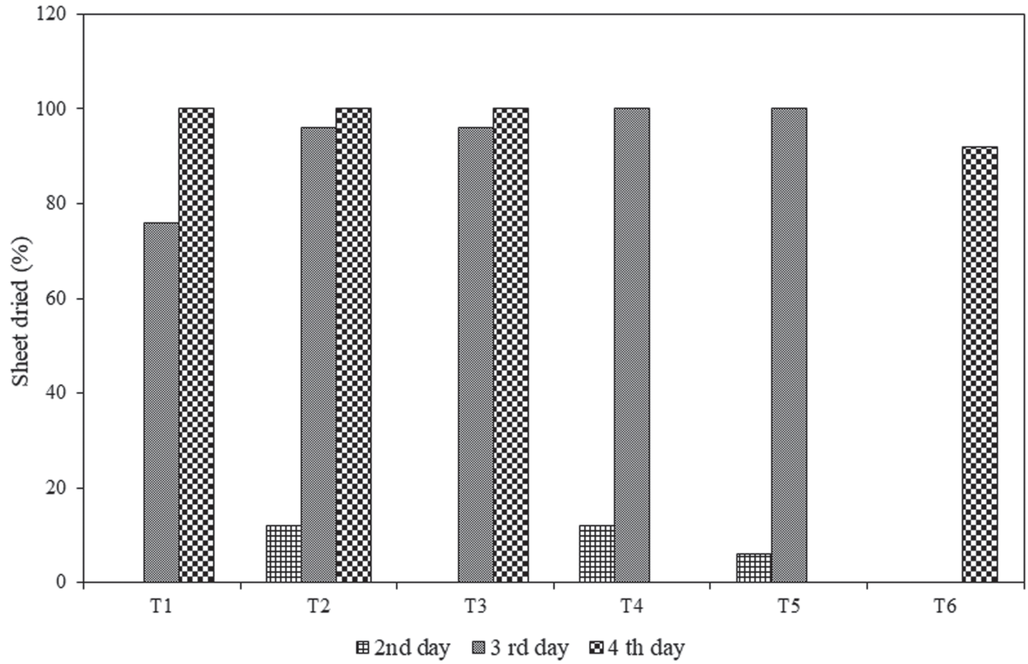

Fig. 3. Duration for sheet drying

different GPCs due to various factors. The experimental data was generated from the GPCs without changing their normal mode of operation. Quantity and type of firewood preferably of hardwood (eg. *Tamarindus*, Anjili or rubber) used for better heat build-up with less smoke, frequency of smoking *etc*. vary in GPCs which reflect in drying time and the quality of the sheet recovered (Edgar, 1958; Nair *et al*., 1988). Four days of daily smoke drying is required to produce RSS 1 at Thalakkod, whereas two days daily smoking was needed for RSS 2 grade at Thiruvilluamala and four days alternate days smoking needed to produce RSS 1 at Manimooly GPC. This indicates the different systems followed for drying of sheets in GPCs. The experimental sheet recorded a recovery of 92 per cent at Thalakkod and 96 per cent at Thiruvilluamala as against 82 and 74 per cent recovery, with their normal practice. Blister formation in about two per cent of the control sheet was noticed in Thiruvilluamala and this may be due to the expansion of internal moisture following high initial temperature (Naunton, 1961). The experiment was repeated in Manimooly GPC as they are producing RSS 1 grade sheet with higher recovery percentage. Drying time taken at Manimooly is depicted in Fig.3. Control (T6) recorded 92 per cent drying on the fourth day. Among the treatments, twin roller showed the highest drying efficiency (100% on the third day) with minimum effort (single pass).

Three days after smoke drying, 86 per cent of the control sheets was recovered as RSS 1 grade whereas additional pass yielded 100 per cent as RSS 1 grade (Fig.4) as per the directives given in the “Green Book”. Treatments T2, T4 and T5 recorded the highest recovery as RSS 1 grade. Excess

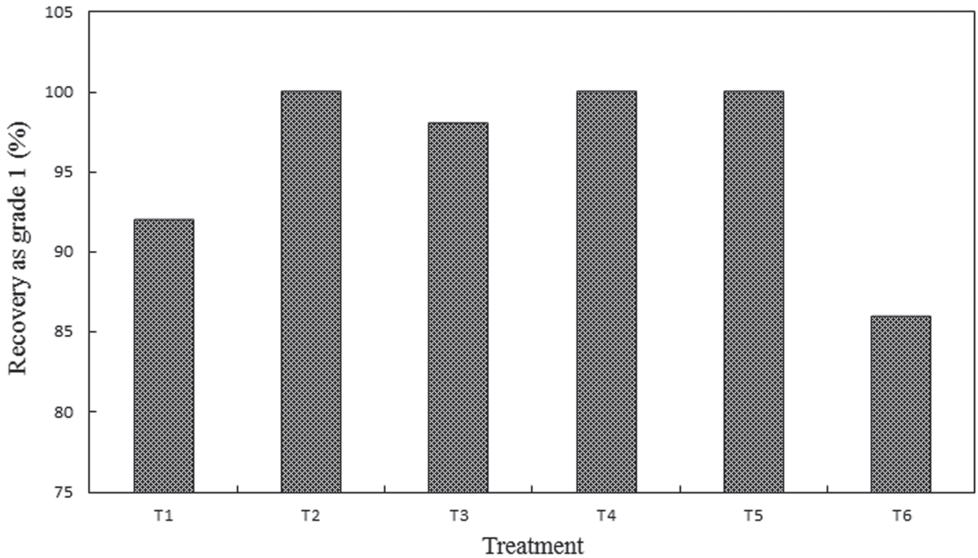

Fig. 4. RSS 1 recovery (%) after smoke drying

deposition of smoke and reaper mark appeared more on the control sheets which made these sheets relatively inferior.

Shrinkage of sheet on drying is mainly on account of loss of moisture. A dimensional reduction of the wet sheet at drying was noticed for the control (T6; 20%), followed by single additional rolling (T1 & T4: 13.3%), and two passes through plain and grooved rollers (T2; 8.7%) (Fig.5). An increase in the dimensional area after drying in contrast to the wet sheets in control was noticed only where the twin roller was used (T5; 5.3%). Control sheets on drying were stiff whereas the sheets that received additional rolling, particularly with twin roller became more flexible.

Drying curve (Fig.6) indicated that initial drying through syneresis was faster with elimination of the major chunk of serum (90-94%) within the first 20 hours of drying, Subsequently it became very slow during the diffusion controlled drying to expel the remaining quantity of the serum. Elimination of remaining less than 10 per cent of water through diffusion process took more than 68 hours (fourth day) in the case of control sheets that received four rolling while the sheet that received additional rolling took only 44 hours (third day). It implies that drying time is governed more by rate of diffusion rather the amount of water expelled through syneresis. As the diffusion occupies the greater part of the drying time (Gale, 1959; Nair *et al*., 1988; Varghese *et al*., 2004; Ng *et al*.,2015), thickness as well as the retention of area during the period are crucial for expelling the serum which is trapped internally and is ensheathed with a relatively dry surface.

The dried sheet measures an average thickness of 2.36 mm and 3.58 mm respectively for experimental sheet (twin rolled) and control. This implies that 34 per cent reduction in thickness could be achieved through additional rolling. The result is in agreement with the earlier report by Edgar

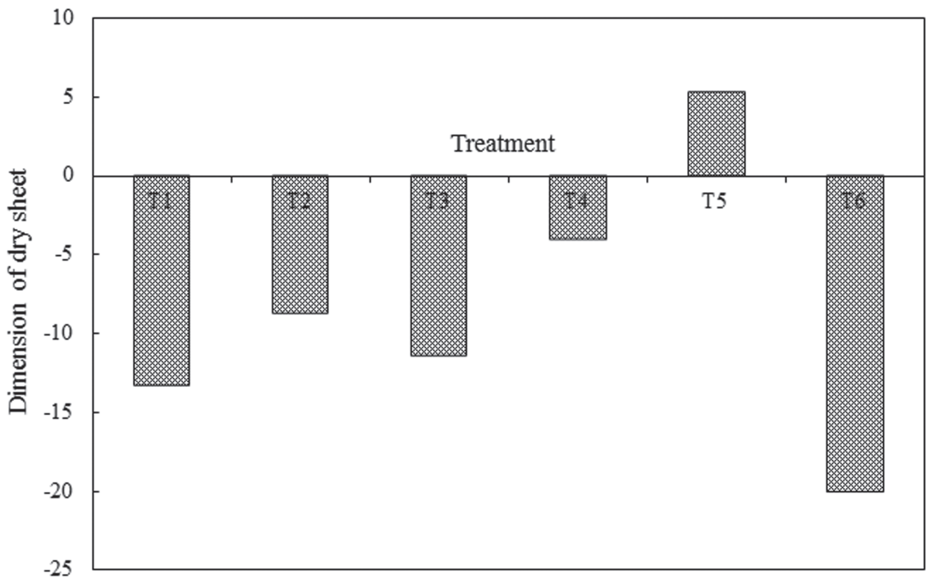

Fig. 5. Dimensional reduction (%) of sheet after drying

(1958) that reduction in thickness (by 12%) reduced the drying time of the sheet by one day from the normal duration. Imprints of the interlocking patterns of a conventional sheet (Fig. 1b) are not changed with additional rolling through plain rollers, but subsequent rolling using ribbed or twin roller altered the surface markings on the sheet (Fig. 1c) and thereby increasing the effective surface area. Additional rolling with plain (T1) and grooved roller (T3) squeezed out equal quantity of serum favouring only in the syneresis, and will not improve the lengthy diffusion process. Among these two treatments, thinning and increase in the surface area with additional imprints, and thereby quick drying was achieved for T3. As the plain roller failed to increase the effective surface area substantially with additional imprints for quick drying, it can't be used for the purpose of providing additional rolling.

Microscopic observations revealed that effective surface area due to imprints (ridges and furrows) increased by two to three fold in twin rolled sheets over control, which is achieved by increasing the number of furrows, and a reduction in width and increasing the number of cris-crossings of ridges per unit area (Table 2; Figs.1 b, c, e, f). An increase in the number of ridges and furrows within unit area, and a substantial reduction in the area of furrows in the experimental sheets attributed for better retention of dimensional area. The cris-crossing regions were thick evident with poor light penetration, and the area comprises with a higher value of 2.26 mm^2 for control over twin rolled sheets (0.76 mm^2). Thickness (μm) in cross sectional view of the sheet under microscope for sheets which received four and five rolling (Figs. 1. g, h, i) was 3400 and 2300 for ridges and 1600 and 1100 for furrows, respectively. It indicates that the thickness of the sheet was reduced substantially through additional rolling, and both the values of ridges and furrows

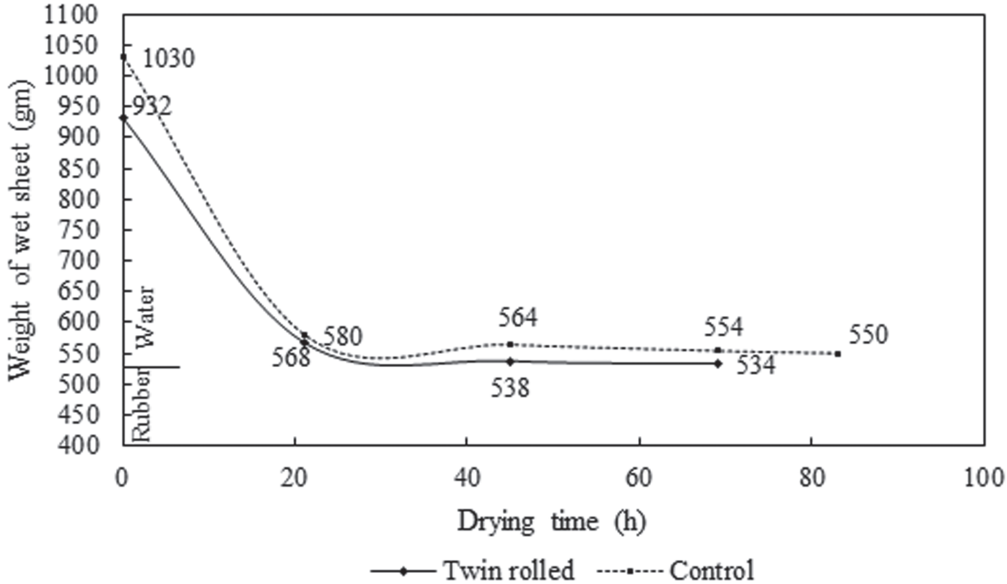

Fig. 6. Drying curve for sheet rubber

for the experimental sheet stands much lower that the thickness of the furrows of the control sheet. Furrows are the thinnest loci in the sheet that dries fast while, the material dense ridges took maximum time for drying. As the cris-crossing locus is thick and experienced a lengthy drying time, further modification to the characteristics of grooves of the roller needs to be addressed.

The anticoagulants, excessive acid content and high water retention in the wet sheet not only delay the drying but affect the colour required for RSS 1 grade sheet (Iyer, 2013; Rubber Board, 2015). Along with the additional serum squeezed out in the new method a substantial amount of anticoagulant and acid get eliminated which in turn improves the colour of dry sheet (Fig.1d) and safeguard the sheets from excessive deposition of smoke, and the formation of blisters as reported by Roudeix (1985).

Sheet with mild quantity residual moisture are vulnerable to fungal growth even for short term storage. The residual moisture in many instances is not so easy to detect visual grading and is a matter of serious concern for the sheet dealers. The advantages observed in the present study

Table 2. **Characteristics of furrows and ridges on dry sheet**

Character	Control	Twin rolled
Furrows		
Number/unit field	6-7	16-18
Area (mm^2)	0.14	0.03
Thickness (μm)	1600	1100
Ridges		
Width (μm)	628.8	356.5
Thickness (μm)	3400	2300
No. of overlapping/unit field	5-6	15-16
Area of overlapping (mm^2)	2.26	0.76

may solve this long pending issue to a great extent.

The data generated from were revalidated at Poothrikka GPC equipped with two separate sheeting batteries having four and five sets of rollers, respectively - of the five sets two were ribbed and produced RSS 1 sheet (96-100%). Average wet weight for fresh sheeted coagulum recorded 1kg and 0.930kg those delivered from the battery with four and five sets of rollers implies that an additional 0.098 kg of water was expelled by additional rolling (Fig. 6). The average dimensions of wet sheet from the old machine with four sets of rollers was 70cm x 42cm (2940cm^2) and for the new machine with five sets of rollers was 88cm x 46cm (4048cm^2). After 24 h of drying, about 90 per cent of the serum had come out with a substantial reduction in the dimension by 21 and 30 per cent, respectively for the sheet produced from the old and new machine (Table 3). Thickness of the sheet also reduced within 24h. of drying. Sheets that received extra rolling got dried (96%) on the third day (64 hrs) while the control sheets got dried (94%) in the fourth day (88 hrs). Thick dired sheets are comparatively stiff in nature. Across the dried sheet, better dimensional retention for breadth (tip of the sheet: intermediary region: middle part with mild reaper mark) was observed for the sheets received additional rolling (41cm: 40.5: 42) over control (33.5cm: 32: 35). After drying, shrinkage recorded for sheets from the old and new machine at Poothrikka GPC was 25.7 per cent and 30.1 per cent respectively. Even though the value for shrinkage was higher for new machine (2830 cm^2), the size of the sheet was more or less comparable with that of wet sheet produced by the old machine (2940 cm^2), prior to drying. The number of thick spots recorded due to interlocking in dried sheets of old and new machines were 93 and 266, respectively in a unit area of 25 cm^2 indicating that effective surface area for drying was substantially increased due to additional imprinting. The change in the surface markings with the new machine was not considered as a criterion by the traders while grading the sheet visually. The revalidated data is in agreement with the earlier experimental data generated from the other three GPCs endorsing the advantages of the improved method.

Economics

Cost for drying of wet sheet forms a major share in the processing cost of sheet rubber. During the peak yielding season, Manimooly GPC produces on an average 1000 sheets (approximately 500 kg) per day. Their daily expenditure for the conventional

Table 3. **Characteristics of sheet at Poothrikka GPC**

	Four rolling (old machine)		Five rolling (new machine)	
Dimension of sheet	L x B (mm)	Area (mm^2)	L x B (mm)	Area (mm^2)
Wet sheet (fresh)	70 x 42	2940	88 x 46	4048
After 24h.	61 x 38	2318	70 x 41	2870
After drying	58 x 37.5	2184	69 x 41	2829
Thickness (mm)				
Wet sheet (fresh)	5		3	
After 24h.	4.5		2.5	
After drying	3.58		2.36	

Table 4. **Expenditure for producing quality sheet rubber**

Item	Conventional method	Modified method	Saving
No. of days for drying	4	3	1
Fire wood cost (Rs/-)	4.00	3.00	1 .00
Wages (Rs./-)	5.60	4.60	1.00
Chemicals (Rs./-)	2.00	2.00	-
Electricity (Rs./-)	0.10	0.12	-0.02
Transportation (Rs./-)	3.00	3.00	
Total (Rs./-)	14.70	12.72	1.98

method and savings by adopting modified method were worked out on per kg basis and are given in Table 4. Cost estimated for producing one kg of RSS 1 sheet rubber is Rs.14.70 which could be reduced by Rs.2/- per kg by the modified method.

Translucent stains like dark reaper mark appearing while drying is a concern for producing quality sheets. The practice of one time turning of wet sheet on the second day of drying to avoid the marks is a tedious operation in the smoke house. One labor is utilized for about thousand sheets, *i.e.,* 500 kg per day. This practice can be skipped in the new method as the sheets are not sticky and produced without reaper mark and thereby reduce labor cost.

Paucity of space for the smoke house is a constraint in most of the GPCs. By adopting the new method smoke drying can be completed one day earlier. The space thus saved (25%) can be effectively utilized for drying additional 25 per cent sheets without additional cost for firewood. New sheeting batteries with five sets of rollers (three plain followed by two grooved ones) are introduced recently with an additional expenditure of Rs. 5000/- over the older version of sheeting battery with four sets of rollers.

It has been reported that if the sheet is machined too thin, the cost of machining, the space required in the smoke house and the difficulties in handling are more (Piddlesden, 1936; Varghese *et al*., 2004). More than 25 GPCs in Kerala have recently installed, and a good number have placed order for the new sheeting battery with the facility for providing additional rolling indicating the keen interest in adoption of the new methodology.

CONCLUSION

An improved methodology for quick drying was developed for reducing drying time of sheets by increasing effective surface area by giving an additional rolling. Additional rolling, particularly with twin roller will (a) reduce the thickness (b) remove the anticoagulant and cellular residues along with the serum squeezed out, (c) eliminate the sticky nature of the wet sheet (d) hasten drying (e) lead to better retention of dimensional area for dry sheet (f) save fuel (g) improve space utilisation in the smoke house and (h) provide better colour for the dry sheet. The new innovation can be adopted by GPCs either by upgrading the existing machine or by adding a new roller. Small growers can provide an additional rolling through the existing conventional ribbed roller, without any additional financial implications.

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