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A New Method for Quality Improvement of Sheet Rubber for Marginal Rubber Growers in India

Vinoth Thomas, T.P.Radhakrishnan* and Joy Joseph

Rubber Research Institute of India, Rubber Board, Kottayam- 686 009, Kerala, India
**Rubber Production Department, Rubber Board, Nilambur- 679 329, Kerala, India*
E-mail: vt@rubberboard.org.in

Abstract: Rubber plantations spread over ten lakh hectares of land in India is predominantly owned by small holders having an average plot size of 0.5 ha., majority of them prefer to dispose and their produce as sheet rubber. Their traditional wisdom in making sheet rubber has the advantage over other forms of rubber for ready and better realization of price as they can be disposed at any time in a fluctuating market. Making sheet rubber involves latex coagulation, sheeting and subsequent drying, which together takes four to five days for completion. An improved method for quick preparation of sheet rubber was achieved by replacing the conventional coagulant Formic acid with a mixture of Acetic acid and Isopropyl alcohol coupled with an improved sheeting procedure. Thirty minutes is enough for latex coagulation in the new method over hours together for conventional method. Tender nature of coagula, through additional rolling which resulted in an increase in the dimensional and surface area through imprinting, thinning and squeezing out of the serum load followed by immediate loading of wet coagula in the hot smoke house together facilitated faster drying of sheet rubber within 24hrs. Raw rubber properties and vulcanizate properties of the sheets prepared by the new method were comparable with the control. Scaling up programme of the new method was carried out among a group of marginal farmers who prepared and disposing partially dried or inferior quality sheet rubber at a lower price. Periodic assessment by a team of experts for the extent of execution of the new method resulted in the upliftment in the quality of their produce in the competitive market. The advantages attributed with the new sheeting method are: saving time and cost of primary processing, quality up-gradation through awareness, introducing the involvement of female counterpart, in addition to early disposal of the consignment which is more beneficial particularly for farmers where rubber is the sole source of income for their daily lively hood.

Keywords: *Hevea brasiliensis*, Latex coagulation, Marginal rubber farmers, Natural rubber, Primary processing, Quick sheeting, Properties of ribbed smoked sheet.

INTRODUCTION

Natural rubber is an industrial raw material mainly collected as latex on tapping the bark of the deciduous tropical tree- *Hevea brasiliensis.* The rubber tree with a history of more than a century is cultivated as plantation crop in ten lakh hectares of land across the country. The traditional rubber growing tract comprises of Kerala, Tamilnadu and Karnataka, and is extended to non- traditional areas especially North Eastern states of India [29, 28, 26]. Latex is a colloidal system constituted of serum, 30-45 percent rubber and 2-4 percent non rubber constituents [21]. More than eighty per cent of the total natural rubber latex produced in India is being processed as ribbed smoked sheet rubber (RSS) in which the prime contributors are small farmers and Group processing centers (GPC) [23, 32]. Driven by industrial demand, majority of small growers produce RSS 4 or lower grade sheet in their own house hold with the available infrastructure [10]. Even though latex coagulation

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and subsequent drying of sheeted coagula is a tedious and lengthy process in the course of primary processing, majority of the producers continued to produce sheet rubber due to the unique advantages. The price of sheet rubber fluctuates quite often, and therefore, growers are prompted to store the sheets to sell at the right time, which is the prime advantage of sheet making. The steps involved in sheeting of the latex coagulum and smoke drying are important in the production of good quality sheets within a reasonable time. During primary processing, drying the sheet takes more than 80 per cent of the time. The nature and thickness of wet sheeted coagula, serum content entrapped after rolling, retention of effective surface area are important factors affecting sheet drying [16, 15]. Drying time for smoked sheet can be reduced by 25 *percent* in three days, by further thinning and increasing the effective surface area of the wet coagula, and removal of excess water content entrapped by providing additional rolling with grooved roller [24]. Quick preparation of sheet rubber has advantages of saving time and processing cost in addition to early disposal of quality produce, particularly for small grower's sector where rubber is the prime source of income. More than ten lakh farmers in India, primarily small holders, who hold more than 80 per cent area and produce 93 per cent natural rubber, depends on rubber which caters to their daily need [32, 8]. In many instances, they are prompted to dispose their consignments even with partial drying to fetch an unimaginably low market price decided by the local dealer. This is an area where the marginal farmers are being cheated openly since long which needs special attention. In this context, a new approach for quick sheeting and subsequent drying for producing quality sheet rubber within a reasonable time was standardized, and the feasibility of the method among the marginal farmers was assessed.

MATERIALS AND METHODS

Fresh field latex collected 3hrs after the commencement of tapping, i.e., at 10 AM was used for standardizing the new method along with the conventional method as control [19]. After sieving, 1.5 litres of latex (expected dry weight of the sheet as 500 g) was poured into 100ml of water taken in a container. The latex thus diluted was poured into a dish which spreads with the coagulant prepared by mixing freshly prepared (1) 15ml of 25 *percent* Acetic acid, (2) 15ml of 25 *percent* Isopropyl alcohol and (3) 50 ml of water, and mix well while pouring the latex into the coagulant mixture. While pouring the latex thorough mixing with coagulant is to be ensured in order to avoid uneven coagulation. After thirty minutes the wet tender coagula mass was taken out, and then pressing by passing three times through plain roller and two times using grooved roller for ensuring thinning, stretching and squeezing out water as described by Thomas [24]. Wet and tender sheeted coagula after thorough washing was immediately loaded in the hot smoke drying house by 11AM on the same day of tapping. Sheets prepared by standard procedure as control, with the expected dry weight of 500g, underwent three pass through plain roller and one pass through grooved roller and were loaded in the same smoke house after dripping for an hour by 11 AM on the next day of tapping. Measurements on dimension and weight of the wet and dry sheets were recorded periodically.

The compounding ingredients such as zinc oxide (ZnO), stearic acid, TDQ, CBS, Sulphur, etc. used in this study were supplied by Bayer (India) Ltd. Naphthenic oil was supplied by Samira Chemicals Pvt. Ltd, Kottayam and carbon black (HAF) was supplied by Vision Enterprises, Mumbai. All other chemicals used were of laboratory reagent grade. The cure characteristics were studied using RPA 2000. The plasticity parameters (P0 and PRI) were measured using a Wallace Rapid Plastimeter MK V-P14 and MRPRA ageing oven as per ASTM standards [1]. The Mooney viscosity [ML (1+4) 1000C] was measured using Mooney viscometer model V-MV 3000. The heat buildup was determined using Goodrich flexometer. Tensile properties, Tear strength, heat buildup, compression set and hardness were tested as per the respective ASTM standards D412, D 624, D 623, D 395 B, and D 792 / 2240.

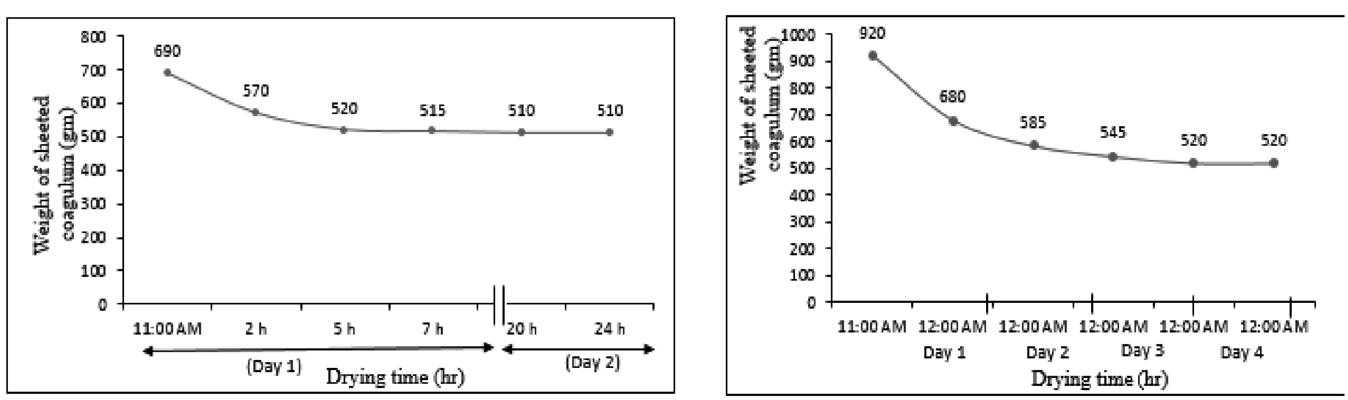
After standardization, the method was extended in a small scale in two Group processing centres (GPC) at Poothrikka and

Kavalangad in Ernakulam Dist. for evaluating the repeatability. Revalidation and scaling up of the programme was carried out further in the holdings of ten marginal rubber growers under Regional Office (RO) of the Rubber Board, Nilambur with the support of M/s.Thunchathu Ezhuthachan Rubbers (P) Ltd., Nilambur for a period from December- February 2022. A training programme on new sheeting method was also arranged for ten selected farmers at Moothedom and Vaniambalam Rubber Producer's Society (RPS) under RO, Nilambur. A team of experts visited the farmers periodically for assessing introduction of the new sheeting method and the involvement of family counterpart in primary processing and quality of the sheet produced by them thereafter.

RESULTS AND DISCUSSION

Formation of rubber coagula with the new method took 25- 30 minutes when diluted latex was poured into the conventional Aluminium dish containing freshly prepared 15ml each of 25 *percent* acetic acid and Isopropyl alcohol poured separately as coagulant. The process is endothermic and the coagula thus formed was tender with a clear serum and is to be made into workable form by adding 500ml of water followed by pressing the same with hand for 2-3 minutes, if required with respect to clone, season and dry rubber content (DRC) of the latex used. The coagula thus matured was sheeted by rolling three pass through plain roller followed by two pass using ribbed roller, which makes the sheet thin without tearing, increasing the surface area and enabling to squeeze out more serum from the wet coagula. The wet sheets were washed thoroughly for removing coagulant and cellular debries, and loaded without delay in the smoke house made ready at 70°C for drying.

Immediately after passing through the sheeting roller, a wet ribbed sheet contains both rubber and serum, and it is a diphasic medium during drying [2]. A fresh wet experimental sheet measured an average length of 82cm and breadth of 44cm with 3608 cm^2 area while, the control sheet have 72 x 42cm dimensions with an area of 3024 cm^2. 19.4 percent increase in area over control sheet was achieved by the tender nature of the wet coagula together with additional rolling. Once the interlocking gets imprinted on the sheet with cris-crossing of ribbed rollers, further dimensional increment through subsequent rolling can be made only to a limited extent as the case with control sheet. It has been noted that even though the coagula is tender to handle, no tearing was noticed while rolling. The wet sheeted coagula of control is then allowed to hang for one hour under shade to drip off water due to syneresis- expulsion of serum from the latex coagulum by contraction of the structure of rubber particles [18] before it is fed into the smoke house. The time taken by the experimental sheet for this process was saved by immediate loading of the wet sheet for drying. Once the coagulum get sheeted it becomes hard as the time proceeds and elimination of water is delayed.



New method Conventional method

Figure 1: Drying curve for sheet rubber

Wet sheeted coagula retains 26 and 43.5 per cent water respectively for treatment and control by using the same quantity of latex for coagulation (Fig.1). Low level of water retention after additional rolling favour faster drying which took 24h for treatment while 96h is required for control. The dried treatment sheet checked at 6PM on the same day showed few scattered white dots, particularly on the ridged portion of the sheet which gets completely dried in the next day by 10AM (Fig. 2). Drying of the sheet took 20-24 hours for completion. This observation is in agreement with the earlier finding that softness of the coagula expel both surface and interior moisture in a faster manner through the process of syneresis and diffusion as observed by Thomas [25] during the drying of DRC samples prepared for quick determination of rubber content in the latex. Diffusion is a slow process which comes in the later part of sheet drying and took 20h and 60h respectively for treatment and control to expel ten per cent of the entrapped water at the end of drying. Latex is regarded as rubber particles in serum dispersion which has inverted its phase to serum in rubber dispersion after machining the coagulum [20]. Additional rolling has the advantage of inverted phase of rubber and serum as suggested by squeezing out excessive serum entrapped, in addition to thinning (Fig.3) and increment in dimensional and surface area which favour the process of syneresis and diffusion process.

Among the dried sheets, better dimensional retention for both length and breadth (tip of the sheet, intermediary region and middle part with mild reaper mark) was noticed for experimental sheet over control. Loss of water while drying resulted in shrinkage of sheet dimension towards the end by 13.5 and 20 percent for treatment and control respectively. Retaining more dimensional area have advantage of expelling moisture particularly towards the end of drying. Control sheets on drying were stiff whereas the experimental sheet feels to be more flexible may be resultant of thinness. The number of raised imprints (Figs.4,5) developed due to interlocking while rolling the experimental and control dried sheets recorded 248 and 82 respectively in a unit area of $25cm^2$ indicating that effective surface area for drying was substantially increased and are not interfering for traders while visual grading of sheet rubber.

A comparative study for raw rubber and technological properties of the dried sheets were carried out. The raw rubber properties are shown in Table 1. The results showed that the PRI is slightly lower for the treated sheets. However the PRI values are well within the limits. Other parameters are on par with the control.

Table 1: Raw rubber properties

Parameter	*Control*	*Treated*
P_0	29	28
PRI	90	82
Mooney viscosity (ML(1+4) 100°C)	54	54
Colour	Honey colour	Honey colour
Protein	2.7	3.3

The sheets were compounded as per the formulations shown in Table 2 and various vulcanizate properties were studied. The results were compared with a control.

Table 2: Formulation of compound

Ingredients	*Quantity (phr)*
Rubber	100 (phr)
ZnO	5
Stearic Acid	1
Antioxidant	1.2
SRF black	40
Napthenic oil	2
CBS	0.9
Sulphur	2.5

Cure characteristics

The compound was analyzed for various cure characteristics and the results are shown in Table 3.

Table 3: Cure characteristics

Sample	*Cure characteristics*				
Particulars	*$S'M_L$ dNm*	*$S'M_H$ dNm*	*Tan δ M_L*	*Tan δ M_H*	*T90 (min)*
Control	1.13	14.43	0.88	0.05	6.34
Treated	1.29	15.15	0.83	0.05	6.27

The results showed that the initial torque $S'M_L$ and final torque $S'M_H$ were slightly higher for the treated sample compared to control. Tan δ was smaller for the treated sample. T90 was almost on par with that of the control.

Technological Properties

Table 4: Technological properties

Properties	*Control*	*Treated*
Tensile strength (MPa)	25.25	25.90
Tear strength (N/mm)	100	109
Modulus 100%(MPa)	2.34	2.63
Modulus 200%(MPa)	4.92	5.17
Modulus 300%(MPa)	9.61	9.71
EB (%)	567	565
Compression set (%)	35.91	35.62
Heat buildup (^{0}C)	11	13
Abrasion loss (mm^3)	105	107
Hardness (Shore A)	58	58.00

The results showed that the tear strength is slightly higher for the treated sample compared to control (Table 4). Other vulcanizate properties are on par with the control which shows that the treatment does not affect the vulcanizate properties of the sheets prepared by this method.

Economics

Among the different aspects of cost involved, cost for drying of wet sheet forms a major share in the processing cost of sheet rubber [11]. It is estimated that drying of one kilogram of sheet rubber needs one kilogram of firewood. Cost estimated for producing one kg of RSS 4 sheet is Rs.10.60 which could be reduced by Rs.2.40 per kg by the modified method (Table 5).

Table 5: Expenditure for producing quick sheet rubber

Item	*Conventional method*	*New method*	*Saving*
No. of days for drying (in hrs)	96	24	72
Fire wood cost (Rs)	4.00	2.00	2.00
Wages (Rs)	5.60	4.00	1.60
Chemicals (Rs)	0.80	2.00	-1.20
Electricity (Rs)	0.20	0.20	-
Total (Rs)	10.60	8.20	2.40

As on today, price for RSS 4 grade sheet rubber by the local rubber dealer's is Rs.150/kg. A marginal farmer who is disposing the partially dried sheet on the next day can fetch a maximum of Rs.120/kg depending upon the visual grading for moisture entrapped in the sheet (Table 6). The new method enables to dispose quality sheet at a higher price where by the farmer can earn an extra amount of Rs. 30/kg from the produce. By reducing the processing cost together with quality improvement, net amount that can be recovered is Rs. 32/kg. This is one of the ways by which income generation can be enhanced for marginal rubber growers.

Table 6: Price realized for sheet produced by two methods

Item	*Price (Rs)*
Conventional method	
Current market price for RSS 4	150
Market price for partially dried sheet on the next day (realized price)	120
Loss due to conventional method for a marginal farmer	30
New method	
Price realized for quality sheet (RSS 4)	150
Processing cost (Saving)	2
Net incomed realized by the new method	152

As the sheet needs four days for smoke drying, the capacity of the smoke house is estimated as four times the production of sheet in a day. Paucity of space for the smoke house is a prevailing constraint. Modified method enables to dry the wet sheet within 24 h. in contrast to the 96 h. for the conventional method of processing. It has been reported that if the sheet is prepared too thin, the cost of machining, the space required in the smoke house and the difficulties in handling are more [17, 30]. But, quick drying achieved as a resultant of thinning and expulsion of entrapped serum through additional rolling of tender wet coagula merits in net income.

Thomas [25] developed a quick and easy way of determination of dry rubber content in natural rubber latex by a reverse coagulation method of pouring latex drop by drop into the coagulant in order to avoid entrapping of latex within the instantly formed coagula. In the new method of latex coagulation a simultaneous thorough mixing is to be ensured with a pan for avoiding patched agglomarisation within the coagula. Coagulation is the process of destabilization of latex that occurs with a set of diverse actions either individually or in combination. Addition of coagulant, release of B- serum from a non-rubber component- (lutoids) and/or increasing the volatile fatty acid content (VFA) in the latex by bacterial action can lead to latex coagulation [21, 3, 7]. The latex coagulant neutralises the negative charge existing in the adsorbed surface layer of rubber particles in the latex, constituted of proteins and phospholipids, whereby the rubber particle agglomerates into a large mass or coagulum [13]. Apart from the charge neutralization, the coagulant breaks the two colloidally antagonistic systems by rupturing the lutoid membrane and releasing B serum into the C serum of the latex [21, 3]. The amount of coagulant largely determine the character of the coagulum, which may be soft or stiff, in which the former have better workability particularly in rolling and subsequent drying [4, 6]. Conversion of fresh field latex to wet coagula was achieved within half an hour due to the combined effect of acetic acid and isopropyl alcohol as coagulant. Acetic acid, a known coagulant for latex, acting as an anion donor for neutralizing the repulsive force existing among the rubber particles through charge neutralization. Sufficient quantity of alcohol coagulate rubber from latex quickly [13]. The alcohol is an energetic dehydrating agent due to its antisolvating action. If its concentration in the serum is sufficiently high, it reduces the normal hydration value of protein layer surrounding the rubber particles which tend to agglomerate rubber rapidly. The dual mechanism involved for coagulation resulted in better workability such as stretching, thinning and squeezing out the entrapped serum which are the added advantages attributed to the new method which in turn favour drying as experienced by Gale [5] on the survey of factors involved in the drying of sheet rubber.

Coagulation can be speeded up with higher concentration of acid to a certain extent, but quick coagulation is not found in the case of fresh latex. The instant and uniform agglomeration observed in the new quick method may be due to the dual effect of dehydrating the hydrophilic lipoprotein that ensheathed the rubber particles, in addition to the withdrawal of repulsive force of rubber particles through charge neutralization. This is an area to be intensified for revealing quick coagulation leading to tender coagula formation with better stability from tearing on rolling, and having a property of fast drying. On storing, mould growth on the sheet rubber occurs which is triggered by atmospheric humidity [12]. A delayed appearance with a comparatively low density of mould growth on sheet produced using the new method over control is an added merit. Mould growth makes the sheet either off grade in the market, or for the same quality enhancent is possible through manual or mechanical washing and drying is viable when there is a significant price difference between ungraded and quality grades such as RSS 4 [9, 31].

Current practice v/s new method

A rubber tapper usually starts his work early in the morning by 6 AM and takes 4-5 hours for completing the alloted task in a day which includes tapping of 300 trees, latex collection and coagulation, sheeting of previous days coagulum and loading the same in the smoke house after dripping the water. In order to complete the task within a reasonable time, a tapper have to work continuously without adequate rest. This is one of the sector where the execution of work with respect to time can be monitored. There is a procedure available for on the day sheeting by adding more quantity of coagulant into the latex, which still takes 4-5 hours for coagulation *i.e.* the coagula is about to ready for rolling by 4PM in the same day [19]. After a laborious work the tapper may not be willing to wait for such a long time just for the purpose of sheeting.

Rubber Board has recommended once in three days tapping particularly for plantations where high yielding rubber clones are planted inorder to minimize the so called physiological disorder termed 'Tapping panel dryness' (TPD) [27, 33] reported to be due to over explotation for latex. In such cases the tapper have to come and do sheeting alone on the next day which might not be a regular tapping day on the holding where d/3 system of tapping follows. Moreover, the owner may not be willing to remunerate for the same. This approach is practically not feasible as tappers prefer to be fully engaged in some other holding. In such instances the wet coagula lying in the coagulation pan for 2-3 days develops thick foul smell due to the dense bacterial development [22, 14].

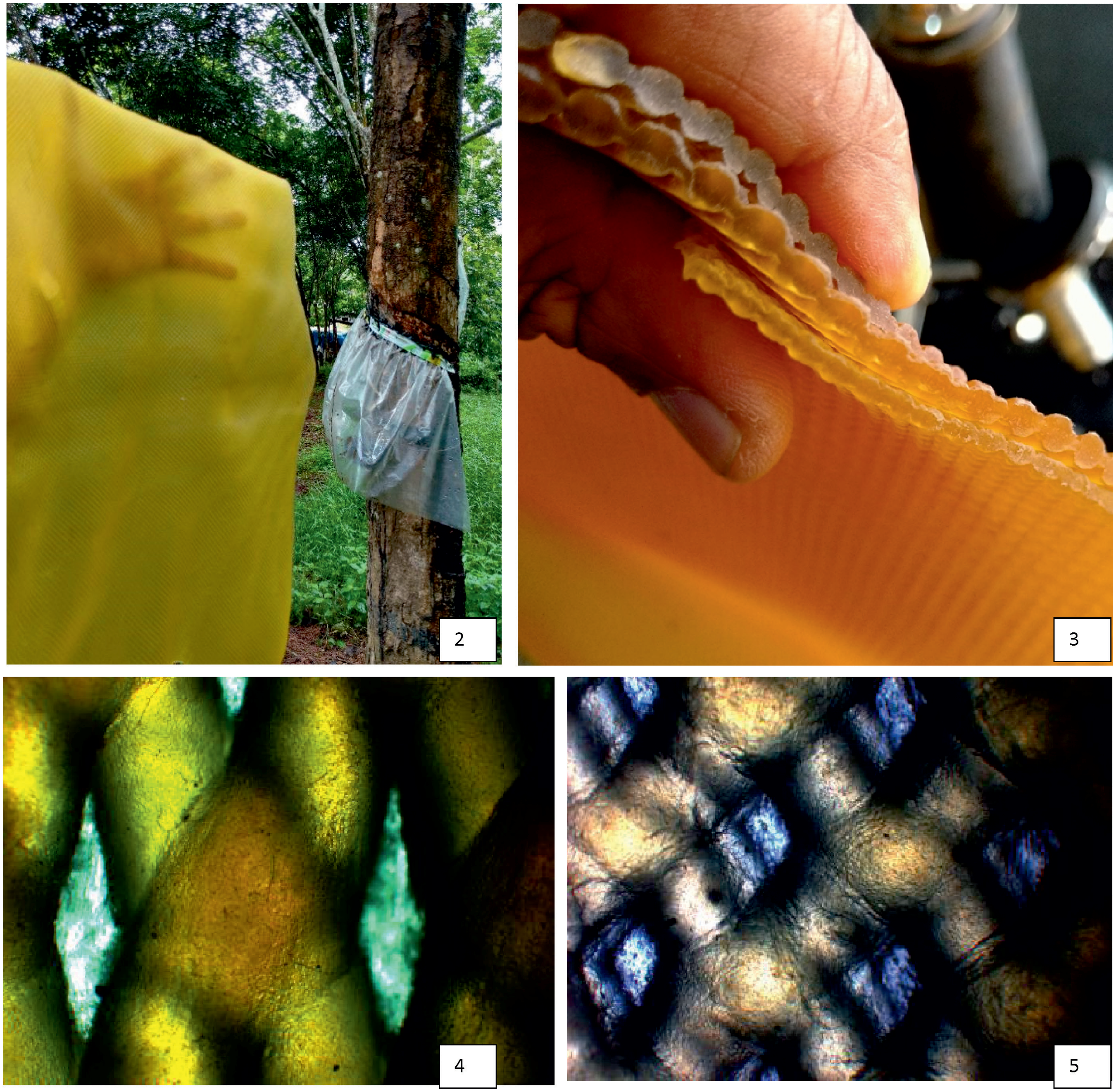


Fig. 2. Dried sheet using new method; 3. Cross sectional view of thin experimental and thick control sheet; 4,5.Cris-cross pattern of control and experimental sheet

The new method enables to do sheeting of latex on the day of tapping in continuation to the assigned task which is convenient for a tapper. High workability of freshly prepared tender coagula without tearing on rolling is the added merit over rolling of next day coagula prepared using the conventional method.

Scaling up of the new method among marginal growers

Feasibility of the new sheeting method after standardization was evaluated among a set of selected marginal rubber growers under the Regional Office of the RP Department of Rubber Board, Nilambur in the Malabar region of Kerala for a period of two months. After a briefing with supportive media, on the next day the farmers themselves produce smoked and dried sheet rubber within a day using their existing infrastructure. On the next day a team of experts visited the holdings for evaluating the quality of sheet produced and imparting necessary advice. The team visited three more times at an interval of two weeks and found that, these growers are equipped for producing quality sheet rubber and gained better price of Rs. 20-25/kg. Moreover, better income from unit land of cultivation through quality upgradation has attracted female counterparts also to involve in sheet making which is an added advantage for this new method.

The new method has ample potential for overcoming the prevailing hurdles in the area of primary processing. Extending the new method for large scale use as the case with Group Processing Centre (GPC) where thousands of sheets is handling in a day, needs certain minor modifications in tune with their routine practice. Feasibility of effective utilization of the existing smoke house is an important area which needs attention. According to the current practice, sheeting is carried out one day after latex coagulation and as a result microbial load and foul smell in the exuded serum will be in the higher side which is facing protest from public. The quick coagulation method which takes only thirty minutes for on the day sheeting to get rid of this problem. Another area which needs scientific intervention is for developing an effluent management strategy with special emphasis on reuse of bulk quantity of water.

CONCLUSION

Among the majority of the Indian rubber farmers who prefer to prepare sheet rubber, there are instances where marginal farmers are forced to dispose wet sheet at a damp cheap market price to meet their daily bread. Quick sheeting method enables to produce quality dry sheet that meets the standard technological properties, so that the farmer can fetch the actual market price. Mould development on storage of sheet rubber particularly during monsoon period is feeble compared to the sheet prepared by conventional method. Flow of quality sheet rubber into Indian rubber market can be envisaged. The new method is energy saving, more economic and make the primary processing of latex more ecofriendly. Moreover, better income from unit land of cultivation has attracted the involvement of female counterparts in sheet making.

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