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Natural Rubber Quality Starts at the Smallholdings: Farmers' Cup Coagulum Production in Southern Thailand

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Thailand has adjusted its production strategy by increasing the manufacturing of standard rubber or block rubber (Standard Thai Rubber or STR) in order to meet global market demand. About 90% of block rubber is STR20, for which the major raw material is cup coagulum. Consequently, demand for this raw material is increasing. The quality of cup coagulum produced by smallholders is so variable. Harvesting and post-harvest practices may influence the quality of cup coagulum. However, this has yet to be studied in Thailand. A study was therefore conducted in Surat Thani province to fill this gap. The methodology combined a survey of 79 farmers using a structured questionnaire to describe farmers' behaviour in cup coagulum production. Analysis of the physical and chemical properties of cup coagulum collected from a subsample of 26 farmers, as well as the properties of the dry rubber obtained from those cup coagula were also carried out. Cup coagula sampled from the 26 farmer subsample were characterised for foreign matter content. The dry rubber samples obtained from the processing of these collected cup coagula (creping-drying) were characterised for initial Wallace plasticity (P_0) and the plasticity retention index (PRI). We found that farmers' harvesting and post-harvest practices were very diverse. A classification of farmers based on these practices was proposed. The quality related parameters showed significant differences between farmers, with some of them being interestingly correlated with certain groups identified by the survey. This study confirmed that the quality of Thai natural rubber starts to be established much earlier than on the factory processing line producing STR bales. Smallholder behaviour may also be of great influence, and training/communication drives could improve the quality of the cup coagulum sold to factories and thereby help the Thai industry to continue producing excellent quality natural rubber.

Keywords: Smallholders practices; natural rubber quality; Technically Specified Rubber; post-harvest practices

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Thailand has been the world's largest natural rubber (NR) producer and exporter since 1991. Around 90% of the rubber planted area in Thailand belongs to smallholders owning less than eight hectares[1]. Until the 2000's, Thai production was mainly exported as smoked rubber sheet. The Thai rubber sector has now adjusted its production strategy by increasing the share of block rubber (STR) in the growing amount of exported dry rubber, in order to match with the global consumption of standard rubber, which has risen sharply over the past ten years. In 2012, Thailand exported around 3.12 million tons of NR[2]. The exported NR was mainly composed of Standard Thai Rubber (STR, 42%), ribbed smoked sheet (RSS, 21%) concentrated latex (19%) and rubber compound (18%)[2]. The STR20 industry is of great economic importance to Thailand, as 90% of exported STR is of grade 20. The raw material used in STR20 production mainly comprises cup coagulum. However, in Thailand especially in southern Thailand, unsmoked sheet (USS) rubber is mixed with cup coagula during STR20 production in order to improve rubber properties and reach the standard properties required by customers. Cup coagulum is coagulated latex in a tapping cup. To form a cup coagulum, the latex is left to coagulate biologically or in some cases supplemented with acid in the tapping cup for faster coagulation.

In general, smallholders choose to produce cup coagulum because it is quick and less time consuming than producing rubber sheets or even latex, which needs to be collected and sold each tapping day. Some impurities such as branches, leaves, or sand may fall into the cup, but sometimes contaminants and impurities may be added to the cup by the tapper. These practices seem detrimental to the quality of the STR20 produced. Once coagulation has occurred, those impurities are attached with the rubber and cannot be easily removed. After cup coagula are collected, they are directly sold to buyers or stored for a period of time before selling. Lastly, the coagula are stored at the industrial site where they will be processed into STR20. Maturation occurs during these storage periods and the maturation conditions also affect the quality of the NR produced[3,4]. Consequently, harvesting and post-harvest practices are believed to influence the quality of the NR produced from cup coagula. However, few data exist and an upstream study of cup coagulum production has yet to be made in Thailand. The objectives of this study which was conducted in Surat Thani province were therefore to describe farmers' practices in cup coagulum production based on a survey including 79 farmers and to investigate the relationship between farmers' declared practices and some properties of the NR made from the cup coagula produced.

EXPERIMENTAL

The methodology combined a survey using a structured questionnaire to describe farmers' behaviour in cup coagulum production, with a study of the properties of the dry rubber obtained from cup coagula. The study methods are described below.

Characterisation of Farmers' Practices

The survey was conducted in Surat Thani province, which is the main rubber producing province in Thailand. Nine districts geographically distributed throughout the province were selected (*Figure 1*). In each district, a sample of farmers was interviewed. Two criteria were used to make up the sample, owning at least one mature plantation, and selling total production as cup coagula. In all, 79 farmers were selected at random from this population. The size of the sample was considered large enough to bring out the

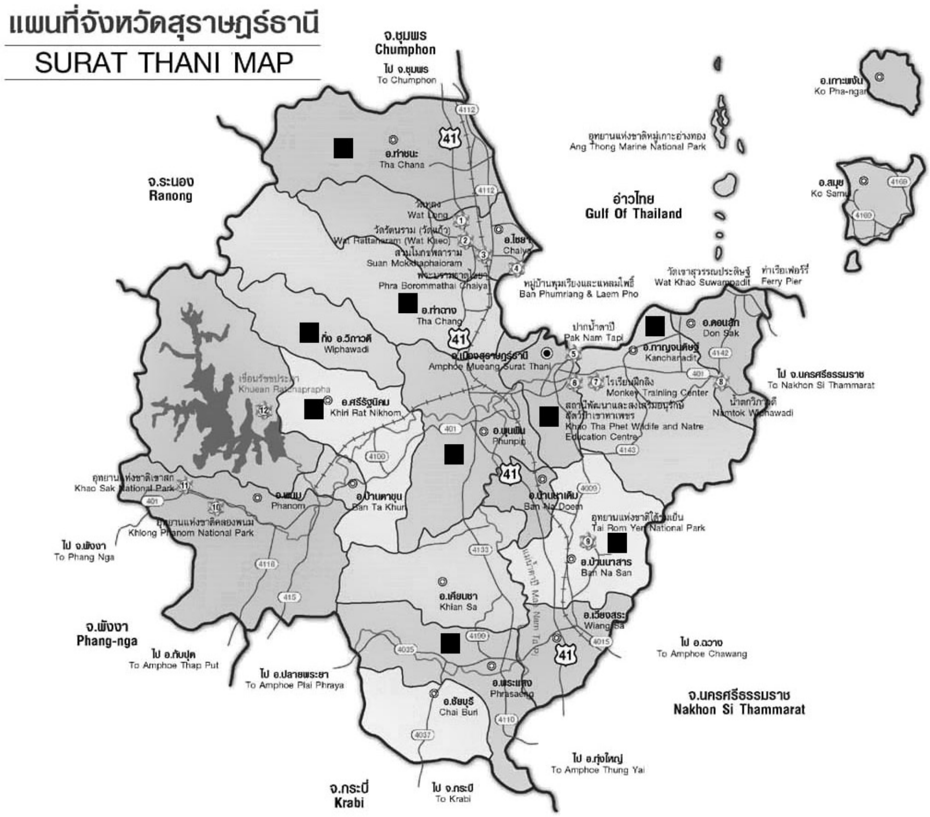
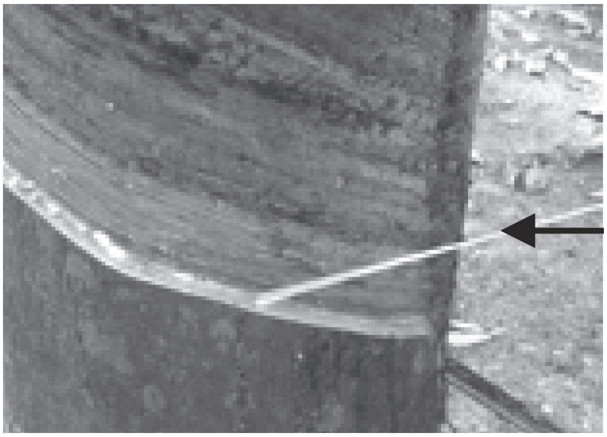


Figure 1. Surat Thani province map with the nine districts selected for the survey indicated with black squares.

diversity of farmers' practices. Data were collected over the 2009-2010 period using a structured questionnaire. Information concerned a description of the rubber plantations, harvesting practices (all practices implemented during tapping) and post-harvest practices (storage). Data were analysed with Sphinx Plus V5 software for univariate descriptive statistics. Variables showing some diversity of farmers' practices and/or assumed to affect cup coagulum quality were used to build a classification. The six variables selected were (i) management of sernamby (ii) management of rubber flow coagulated below the tapping panels (iii) management of rubber coagulated on the ground (iv) management of bark shavings (mixed with rubber or separated) (v) number of tapping days before removing coagulum from the cup and (vi) storage or not of the coagulum after removing from the cup and before selling. Sernamby and bark shavings are illustrated in *Figure 2*. The typology groups were defined after sorting the farmers according to the six previously described parameters. Marginal practices (combination of harvesting and post-harvest practices implemented by only one farmer) were discarded.

A



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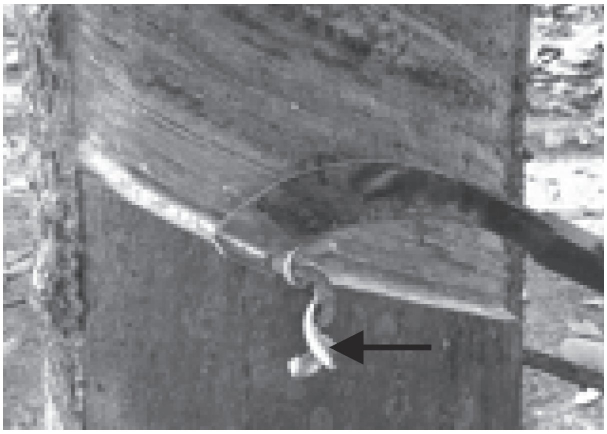


Figure 2. Pictures of (A) Sernamby and (B) Bark shaving.

Analysis of Cup Coagulum Properties

A subsample of 26 farmers from the 79 surveyed farmers was randomly selected for sample collection. Unfortunately, due to time constraints, the subsample was decided a priori before the final results of the classification were known. Sampling consisted of an unannounced visit to the selected farmers and collection of a 5 kg sample from cup coagula ready to be sold. The collections were repeated three times in November 2009, January 2010 and February 2010. Out of the collected cup coagula, for each date, three randomly chosen cup coagula were analysed for their foreign matter content after manual separation. This method was set to get an approximate quantitative assessment of the large size visible contaminants such as bark, wood, leaves, stone, *etc*. To do so, the coagula were cut into small sizes and what appeared visually to be foreign matter, such as wood, stones and other nonrubber elements, were separated manually from the rubber coagulum. The rubber matter in small pieces and the collected foreign matter were dried separately at 100ºC for two hours. After cooling down in a desiccator, the dried pieces were weighed. Drying was continued for a further 30 min up to constant weight. The percentage of foreign matter was calculated by the following *Equation 1*:

$$\%\text{Foreign matter (\%w/w dry coagulum)} = \frac{\text{weight of dry foreign matter (g)} \times 100}{\text{weight of dry rubber matter (g)} + \text{weight of dry foreign matter (g)}} \quad \ldots 1$$

The remaining coagula were stored for 25 days in a bucket (size 38 cm × 51 cm × 17 cm) with holes drilled in the bottom and on the side (hole diameter around 1 cm; density 292 holes/bucket). This duration was based on other surveys (data not shown) conducted in the same region that showed that the cup coagula are generally stored for approximatively four weeks (in middle men premises and factory storage areas) after they left the smallholding and before processing in the factory. The samples were stored outdoors under a roof to protect from direct sunlight and rain in order to obtain storage conditions close to industrial ones. After 25 days of maturation, the samples were creped and dried following a procedure used by STR manufacturers to assess the quality of the cup coagulum stocks. The coagula were creped in a Li Hoe creper (Li Hoe Co. Ltd., Selangor, Malaysia). Gap between nip rolls: 5 mm, friction ratio: 1:1.56, roll length: 71.1 cm, roll diameter: 38.1 cm, engine power: 44.7 kW. Cup coagula were creped by three single passes followed by 18 double passes. Then, each crepe was subsampled into three pieces of approximately 250 g before drying in a hot air oven (UE700, Memmert GmbH & Co., Schwabach, Germany) at 125ºC for two hours.

Plasticity Measurement. The rubber crepe obtained previously was homogenised following Standard Malaysian Rubber[5]. The initial Wallace plasticity (P_0) and plasticity retention index (PRI) were determined according to standards *ISO 2007*[6] and *ISO 2930*[7], respectively.

RESULTS AND DISCUSSION

Some Characteristics of Rubber Plots and Description of Farmers' Practices

Almost all (95%) of the interviewed farmers were smallholders with a maximum of total rubber holding of 50 rais (8 ha). Rubber plantation of less than 1 ha were owned by 21% farmers while 56% owned between 1 and 2.8 ha, 18% owned 3 to 8 ha and 5% owned more than 8 ha with a maximum of 12.5 hectares. RRIM600 was the main clone planted in 93% of the plots, sometimes mixed with one or two other clones: GT1, BPM24, PB235 or PB255. Tapping was often done by the owner or household members. One third of the farms surveyed employed share tappers.

The main tapping system used by 73.4% of the farmers was the third of a spiral tapped three consecutive days and stopped one day (S/3 3d4). The other tapping systems were S/3 2d3 and S/3 4d5 (7.6% of farmers for each), S/4 3d4 (6.3% of farmers) and finally S/2 3d4 and S/4 2d3 (2.5% of farmers for each). Tapping was carried out for 10 to 11 months and there was one to two months without tapping during the seasonal leaf fall period around March and April (wintering period). Stimulation of the trees was very rare (only two farmers) and concerned only old plantations (24 and 28 years old).

Very few farmers (3.8%) used acid for coagulation: 2.5% used it every tapping days and 1.3% when it rained. All of them chose sulphuric acid because coagulation was faster. It is interesting to note that although this is the cheapest and most available acid, it was not the justification given by the farmers for choosing that acid. The reason mentioned by the farmers who chose not to use acid was to preserve the trees, as acid splashing or acid vapour could damage the rubber panel. They also considered that using acid was not necessary.

After tapping, the farmers either separated sernamby, rubber coagulated outside the cup and bark shavings from the latex or mixed them together. *Figure 3* shows that most farmers mixed sernamby, rubber coagulated on the bark below the tapping panel and bark shavings with latex, unlike rubber coagulated on the ground which was mostly not collected. Their main reason for mixing bark shavings, well ahead of increasing the weight of the cup coagula was to accelerate coagulation. When they were not mixed, secondary rubbers were just thrown away.

All the farmers carried out cumulative tapping and cup coagula were usually removed when the cup was full (86% of the farmers). There were between 2 and 12 tapping days before farmers removed the cup coagula, showing a diversity of the level of production and/or a diversity of the size of the cups used. After collecting the cup coagula, some farmers sold them immediately, while others (44%) stored them before selling. Storage was at the plantation for 94% of the farmers while only 6% kept cup coagula in a dedicated storage place. In almost all cases, storage was carried out directly on the ground, increasing contamination of the coagula and without any protection against rain or sunlight (for 97% of the farmers).

Typology of Farmers' Practices

By combining harvesting and post-harvest practices, eight groups of farmers' practices could be identified with at least three farmers involved (named G1 to G8, *Table 1*). Out of the 79 farmers interviewed, eight could not be put into a group due to marginal practices. To avoid multiplying the number of groups or subgroups, the tapping system was not used to establish the classification.

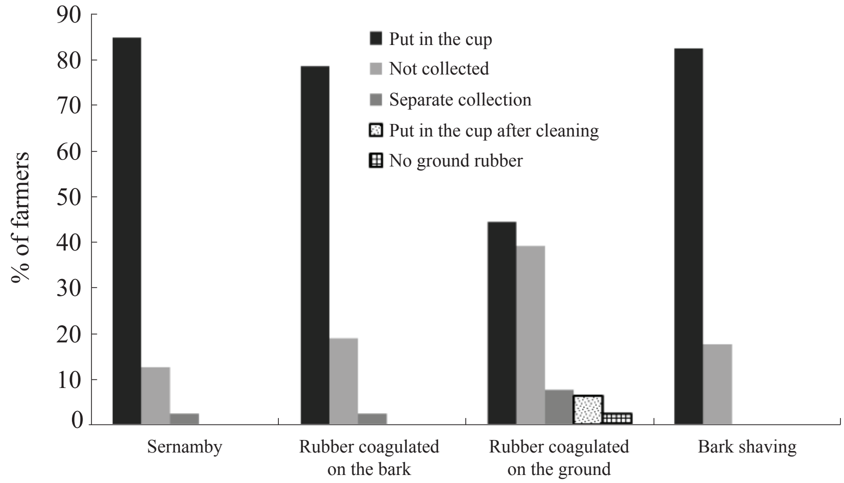


Figure 3. Use of bark shavings and secondary rubbers.

TABLE 1. CHARACTERISTICS OF THE EIGHT GROUPS OF FARMERS' PRACTICES

Group	Characteristics				Number of farmers
	Secondary rubber	Bark shavings	Number of cumulative tappings before collection	Storage	
G1	Separated	Separated	2 – 5	Yes	4
G2	Mixed	Mixed	3 – 6	Yes	16
G3	Mixed except rubber coagulated on the ground	Mixed	3 – 6	Yes	8
G4	Mixed sernamby but separated the rubber coagulated on the ground and rubber coagulated on the bark	Mixed	3 – 6	Yes	4
G5	Separated	Separated	5 – 10	No	6
G6	Mixed	Mixed	6 – 12	No	18
G7	Mixed except rubber coagulated on the ground	Mixed	6 – 12	No	15
G8	Mixed	Separated	6 – 12	No	3

Farmers in G1 did not mix anything with latex; they removed the cup coagula after two to five tapping days and stored the coagula before selling in the conditions described in the previous section. G2, G3 and G4 presented similar characteristics for post-harvest practices where farmers removed the cup coagula after three to six tapping days and stored them before selling. Farmers from these three groups mixed bark shavings with rubber. Practices differed only by the management of the secondary rubbers where farmers in G2 mixed everything with rubber, in G3 they mixed everything except rubber coagulated on the ground and in G4 they mixed only sernamby, (*Figure 2A*) discarded rubber coagulated on the ground and bark shavings. Farmers in G5 did not mix anything with latex; they removed the cup coagula after five to ten tapping days and sold them directly. Therefore, G5 differed from G1 in the post-harvest practices only. Farmers in G6, G7 and G8 presented similar characteristics for post-harvest practices. They removed the cup coagula after 6 to 12 tapping days and sold them directly. However, farmers in G6 mixed all secondary rubbers and bark shavings with latex; in G7, farmers mixed everything except rubber coagulated on the ground and in G8 they mixed all the secondary rubbers but discarded bark shavings. It was not possible to identify any relationship between the groups and the kind of labour (household labour or hired labour) in charge of tapping activities.

TABLE 2. NUMBER OF FARMERS IN EACH TYPOLOGY GROUP WHO WERE INCLUDED FOR RUBBER QUALITY SAMPLING

Typology Group	Number of farmers	Number of farmers included in "quality" sampling
G1	4	3
G2	15	12
G3	8	3
G4	4	0
G5	5	3
G6	18	4
G7	14	1
G8	3	0
No classification	8	0
Total	79	26

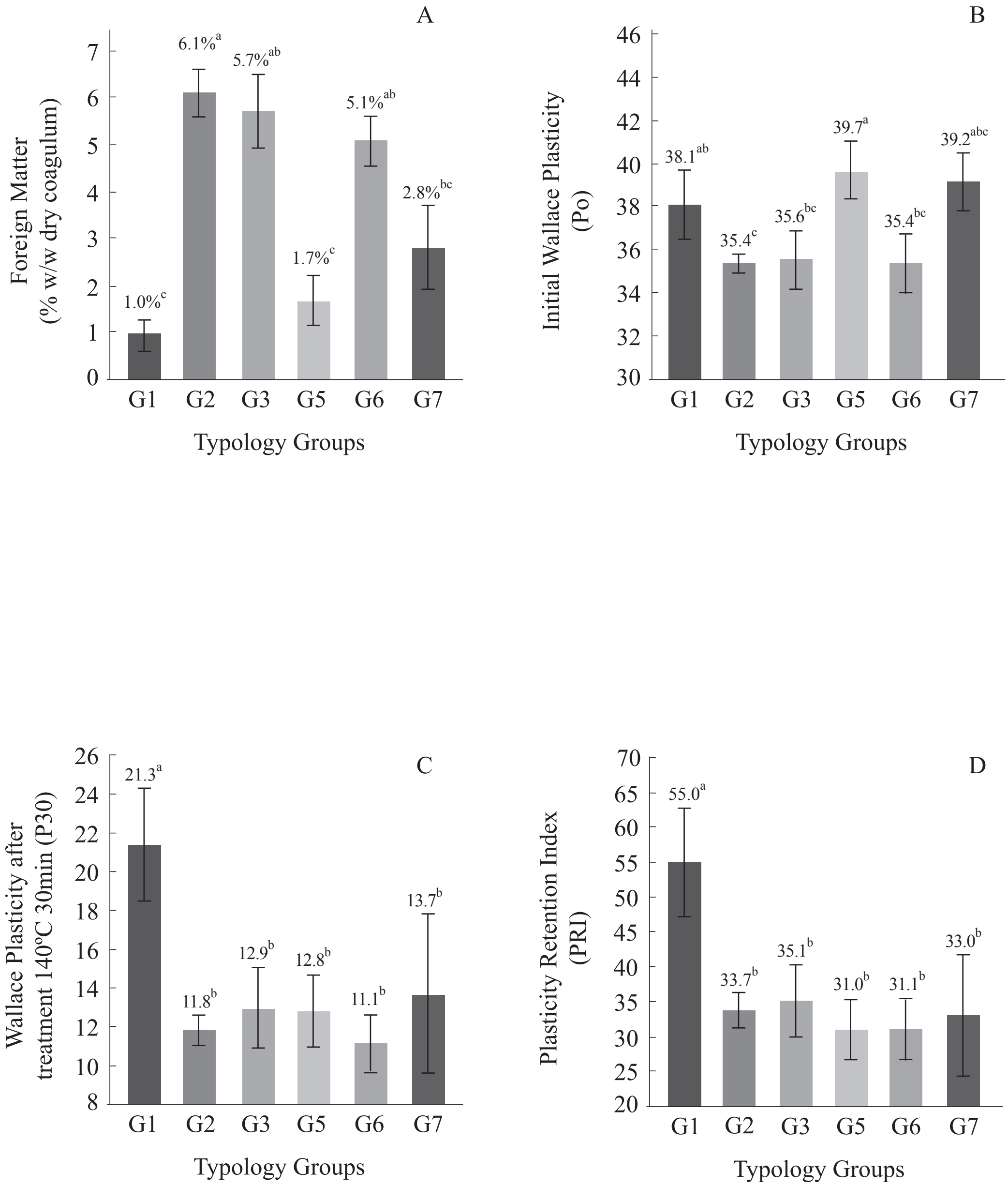
The outcome of this survey showed that there was great diversity in farmers' harvesting and post-harvest practices. This result completes the diversity of farmers' practices after rubber trees started producing, which had already been highlighted by Besson[8] concerning farm management during the mature period and tapping systems.

Cup Coagulum Properties Subsample and Typology

Cup coagulum samples from 26 out of 79 farmers were collected in order to analyse the properties of the NR made from them. *Table 2* shows the number of farmers who were visited in each typology group. As the selection of farmers was based on geographical criteria rather than on typology study results, the number of farmers was found to be not balanced within each typological group, and unfortunately, the cup coagula from two typology groups (G4 and G8) were not sampled at all. However, the study provided enough data to be able to establish relations between rubber quality and farmers' practices.

Foreign Matter

The average amounts of foreign matter measured in cup coagula from each group are shown in *Figure 4A*. They ranged from 1.0 to 6.1% w/w dry coagulum and were mainly composed of bark shavings, leaves and sand. Cup coagula from G1 and G5 contained less foreign matter than those from other groups, which is consistent with the claims of the farmers during the survey. Indeed, farmers from groups G1 and G5 indicated that they did not add any secondary rubbers or bark shavings to the cup. In the case of farmers belonging to G2 and G3, who mixed all secondary rubbers and bark shavings in the cup, the cup coagula they produced were those with the largest amount of foreign matter (6.1 and 5.7%, respectively). The farmers from G7 produced cup coagula with intermediary foreign matter values (2.8%). *Table 1* shows that their claimed behaviour was intermediary. Secondary rubber and bark were added to the cup, but there was no local storage of the coagula, which can be source of contamination. The presence of such foreign matter has environmental, economic and technical consequences.



The error bar represents the standard error of the mean.
Bars with the same letter represent data which are not significantly different ($p < 0.05$)

Figure 4. Quality assessment of the rubber produced by the farmers belonging to different typology groups (A) Foreign matter in the coagula (B) Initial Wallace Plasticity, P_0 (C) Plasticity after heating at 140ºC for 30 min, P_{30} and (D) Plasticity Retention Index (PRI).

Economically and environmentally, the processing of STR20 consumes large volumes of water for washing and cleaning to get rid of contaminants, resulting in the production of polluting effluents and a large amount of solid waste/sludge. Technically, it is claimed by secondary processing manufacturers such as tyre manufacturers, that the presence of impurities, even as small as grains of sand may cause product quality failure (origin of cracks or cuts), thus, endangering the life of passengers.

Standard Properties: Wallace Plasticity (P_0) and Plasticity Retention Index (PRI)

Two standardised properties, namely the initial Wallace plasticity (P_0) and plasticity retention index (PRI), were measured on the NR obtained from cup coagula sampled from the smallholdings. Flow properties were assessed by P_0 while the PRI measured the sensitivity of NR to thermal oxidation.

It was found that the P_0 values of the NR from cup coagula from G1, G5 and G7 ranged from 38 to 40 and tended to be higher than those from the other groups (P_0~35) (*Figure 4B*), though this difference was not statistically significant. It is interesting to note that the highest P_0 were found for the rubber derived from the coagula which contained the least amount of foreign matter. In addition to the environmental and safety consequences of the insertion of foreign matter, this result suggests that it may also have an impact on the rheological properties of raw rubber.

Cup coagula from G1 led to a rubber with a significantly higher P_{30} and PRI than those originating from all the other groups (*Figure 4C* and *4D*). This can be explained by the fact that the practices associated with group G1 were those less conducive to the microbiological maturation phenomena that have been described as being linked to the initial decrease in PRI[4]. Indeed, for G1, no foreign matter was introduced (the latter can be a source of microorganisms) and the cumulative tapping numbers were limited to 2-3, leading to a relatively short maturation time in the cup. However, this needs to be confirmed as the headcount of G1 was rather low and the average P_{30} and PRI values showed considerable variance. Both parameters, impurity introduction and storage conditions were important. Indeed, G5 practices differed from G1 practices mainly in the number of cumulative tappings before collecting the cup coagula (2-3 for G1 and 5-10 for G5). It is known that the maturation of cup coagulum without leaching of the serum is detrimental to the P_{30} and PRI. This resulted in rubbers with the same P_0 but very different P_{30} values (21 for G1 and 13 for G5) and therefore, PRI values (55 for G1 and 31 for G5).

CONCLUSIONS

This multidisciplinary work consisted of a survey conducted with 79 farmers in Surat Thani, Thailand using a structured questionnaire, and characterisation of the quality of NR obtained from cup coagula collected from a subgroup of 26 farmers. It was found that cup coagula harvesting and post-harvest practices were variable. Eight typology groups were found that could describe the practices of 71 out of the 79 surveyed farmers. The product quality assessment part of this study confirmed that farmers' practices did have consequences for the properties of NR. Foreign matter in cup coagulum seem to be related to a decrease in P_0. The number of cumulative tappings before collection of the coagula seemed also to negatively influence the P_{30} and PRI values.

Consequently, if the practice of adding foreign matter and the cumulative number of tappings before collection were to be reduced, it would have positive consequences for the consistency of the rubber produced or at least would reduce the production costs of STR20 factories. Indeed, with better quality coagula, the STR20 factories might be able to use a larger proportion of cup coagula or cup coagulum alone to produce STR20 without special processes. In our study, NR produced from the coagula of G1 farmers satisfied STR20 minimum standard values for P_0 and PRI. A large number of experimental data on these parameters should be collected and studied further to consolidate these initial findings.

Lastly, the harvesting and post-harvest practices implemented by smallholders differed from recommended practices. It is therefore important to gain a better understanding of what drives farmers' practices in order to envisage incentive measures. For example, they claimed that introducing bark shavings accelerated coagulation. Convincing them not to do so would increase the risk of farmers losing production in the event of rain. Taking into account the identified socio-economic constraints and proposing financial incentives are most probably the keys to a successful programme that could incite farmers to change their practices.

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