Economic Proposition for Rural Industrial Sector
EXTRACTION OF TANNIN FROM THE BARK OF ARJUNA TREE

Tannin can be extracted from the bark of Arjuna tree {*Terminalia arjuna)* with warm water as the solvent. Experimental runs were conducted by varying the process parameters viz. size of bark powder, time and temperature of extraction and the amount of solvent one at a time and determining the corresponding yield in each case. Optimum process parameters have been determined to facilitate the commercial extraction of tennin by giving the maximum yield at minimum cost

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India's forest offers immense potential for extraction of valuable chemicals, which can be used as drugs, resins and dyes from natural sources. Tannin is an ideal candidate for commercial extraction since it finds a ready market in leather industry and ayurvedic medical prescriptions. Tannin occurs in varying concentrations in most plant material, but only certain plants contain concentrations permitting commercial utilization. *Terminalia arjuna* is one of the major tannin yielding trees with tannin content of 22-24 percent in bark, 10-11 percent in leaf and 7-20 percent in fruit. The bark also contains 12-15 percent of oxalic acid. Since the tree is indigenous to India and found throughout the sub-Himalayan and Deccan region, Arjuna bark can be procured in large quantities.

Tannin

Tannins are polyphenols that occur in vascular plant tissues. They have an approximate empirical formula $C_{76}H_{52}O_{46}$. Tannins exist primarily in two forms, viz., condensed (Catechol) form and hydrolyzable (Pyrogallol) form. Tannin is used for tanning leather, hardening the fibres of paper, preventing corrosion of fishing nets, in manufacture of inks, as a mordant in dyeing and as a styptic on cuts to reduce bleeding.

Botany of Raw Material

Arjuna (botanical name: *Terminalia arjuna)* is a large deciduous tree with smooth grey bark, spreading branches and small sessile yellowish white flowers. It flowers in March to June and fruits in September to November. Seeds germinate in 50-76 days. This tree is found in the state of Madhya Pradesh, Orissa, Karnataka, Utter Pradesh, Maharashtra and West Bengal. It can be artificially propagated through seeds. One Arjuna tree yields upto 45 kg dry bark chips on a three year cycle without injury.

Extraction & Estimation of Tannin

Tannin was extracted from Arjuna bark by leaching with hot water. Oxalic acid present in the bark had to be removed as it would otherwise interfere with the estimation of tannin. Oxalic acid in the bark was first converted to soluble sodium oxalate by digestion with sodium hydroxide. Calcium hydroxide was added to form insoluble calcium oxalate, which could then be removed from the solution by filtration. The filtrate, free of oxalic acid, contained dissolved tannin. The concentration of tannin was estimated by Lowenthal potassium permanganate titration using indigo carmine indicator. The scope of the experiments are presented in Table 1.

Optimization of Process Parameters

In any process, there is a trade-off between yield and cost. Hence, process parameters are to be optimized to obtain higher yield at lower

Sl. No.	Variable	Range of variable
1.	Particle size, BSS (d_p)	-30+52, -52+60 -60+85, -85+100 -100
2.	Volume of leaching solvent, (V_L) $\left[\frac{cc}{gm\ of\ bark}\right]$	3, 4, 5, 6
3.	Leaching temperature, (T_L), °C	30, 40, 50, 60, 70
4.	Leaching time, (θ_L), hr	0.5, 1, 1.5, 2, 4, 6, 8

Table 1: Scope of the experiment.

Sl. No.	d_p	V_L, cc	T_L, °C	θ_L, hr	Yield, gm	% recovery*
Effect of Particle Size:						
1	- 30 + 52	125	70	0.5	0.438	7.30
2				1.0	0.417	6.95
3				1.5	0.299	4.98
4				2.0	0.452	7.53
5	- 52 + 60	125	70	0.5	0.556	9.27
6				1.0	0.274	4.57
7				1.5	0.280	4.67
8				2.0	0.535	8.92
9	- 60 +85	125	70	0.5	0.629	10.48
10				1.0	0.473	7.88
11				1.5	0.628	10.47
12				2.0	0.645	10.75
13	- 85 + 100	125	70	0.5	0.629	10.48
14				1.0	1.116	18.6
15				1.5	0.962	16.03
16				2.0	1.241	20.68
17	- 100	125	70	0.5	0.928	15.47
18				1.0	1.010	16.83
19				1.5	0.928	15.47
20				2.0	1.031	17.18
Effect of Volume of Solvent:						
21	- 85 + 100	75	70	2.0	0.431	7.18
22		100		2.0	0.511	8.52
23		150		2.0	0.585	9.45
+(16		125		2.0	1.241	20.68)
Effect of Temperature:						
+(16	- 85 + 100	125	70	2.0	1.241	20.68)
24			60	2.0	1.781	29.68
25			50	2.0	2.526	42.10
26			40	2.0	3.203	53.38
27			30	2.0	1.034	17.23
Effect of Time:						
28	- 85 + 100	125	40	4.0	3.42	57.00
+(26				2.0	3.203	53.38)
29				8.0	3.38	56.33
30				24.0	4.05	67.50

Table 2: Yield of tannin from 25 gm of bark chips.
(* based on 24% of tannin content in the bark chips
+ repeated readings to show the effect of an individual variable for optimization)

cost. The following four process parameters were studied for optimization.

Size of Powdered Back: Fine-sized particles offer greater surface area for leaching but there is an increase in grinding cost.

Time ot Leaching: A shorter leaching time will increase productivity of the plant but the leached bark may still contain appreciable amount of tannin.

Amount of Solvent: Use of greater quantity of solvent increases the yield for a single stage leaching but it also increases handling and equipment costs.

Temperature: Since solubility of tannin increases with temperature, higher temperature might favour the yield but would increase heating cost.

Results & Discussion

The effect various process parameters viz. particle size, volume of leaching solvent, the time and temperate of leaching on the yield of tannin are presented in Table 2. As is evident from Table 2, the maximum yield of tannin is at an optimum size of -85 to + 100 BSS mesh. As the fineness of the powdered bark increases, there is an increase in surface area per unit mass of the sample because of which there is a greater interfacial area between solid (bark powder) and solvent (water) resulting in more mass transfer from solid to solvent phase. This could be the reason why the tannin yield is significantly higher at smaller particle sizes and decrease as the coarseness increases. It has been observed that during grinding the coarser fractions have a greater proportion of fibrous material. The fibres, being rich in cellulose and lignin, will have lower tannin content. This will lead to a lower tannin yield from the coarser fractions. There is a high degree of adsorption of solvent by the solid at coarser sizes. The amount of extract obtained is much less even on pressing the leached bark. Thus, the total yield of tannin in the extract will also be correspondingly less. The small decrease in yield at the finest (100 BSS) size compared to the -85 to +100 BSS size could be due to formation of small aggregates of fines there by reducing a portion of the available area for the release of tannin.

The total mass of tannin present in the extract is dependent on two factors, viz., the concentration of the extract and the volume of the extract. If smaller quantity of solvent is used, the concentration of the tannin solution obtained is greater but the volume of extract is less. With higher solvent:solid ratio, the extract obtained has a lower concentration of tannin. The combined effect of these two factors results in an optimum solvent:solid ratio of 5:1. Tannins exist in a variety of form with different hydroxylation patterns each form being more stable under a particular condition. The solubility of tannin in water increases with temperature. However, from experimental data, maximum yield was obtained at the optimum temperature of 40^{U}C. With respect to the leaching time, although there is marginal increase with respect to the yield of tannin beyond two hours, a longer time period will increase the batch processing time. Thus, tannin can be economically extracted from the Arjuna bark chips of -85 +100 BSS size with warm water at 40°C using a chips to water ratio of 1:5 (gm:cc) tor a duration of two hours.

Plant Scale-Up

Various process steps for the extraction of tannin from Arjuna bark is presented in a flow chart (Figure 1). The Arjun bark may be peeled off manually using axes. The chips so obtained should be sun dried before being sent to the grinding unit. A ball mill capacity 75-90 kg bark per day can be used to grind the Arjuna bark chips to an optimum size of -85 to +100 BSS mesh. A screening arrangement will separate the oversize material and return them to the mill for further grinding. Leaching can be carried out in a tank with a capacity to hold 25 kg solids and 125 kg solvent (water). Agitation can be done using mechanical stirrers. Since the optimum leaching temperature is 40°C, which is close to the ambient temperature during summer months, the water need not be heated much. After leaching, the solution should be left undisturbed for some time to allow the solids to settle and then the extract can be withdrawn and the sludge discarded.

A single Arjuna tree can yield 45 kg of bark chips in a three year cycle without injury. Thus, a fully grown tree can be expected to provide 15 kg of bark chips per year. Considering a plantation of 600 trees one can obtain 9,000 kg of bark chips per year. Since the bark chips are prone to fungal attack and need to be stored in a moisture free condition, it is advisable to process the bark chips during the summer season. Not only is the bark easier to peel off and store, but also it is convenient to sun-dry the bark chips without the need of any additional heating/drying medium. Drying the bark chips facilitates grinding. The plant can be run on a seasonal basis during the four months of summer, i.e., February/March to June.

STRIPPING OF BARK FROM ARJUNA TREE TO OBTAIN BARK CHIPS

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SUN DRYING OF CHIPS TO FACILITATE GRINDING

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GRINDING AND SCREENING OF CHIPS

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HOT WATER → LEACHING POWDERED BARK WITH HOT WATER IN AN AGITATED VESSEL

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DILUTE SOLUTION OF TANNIN

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CONCENTRATION AND SPRAY DRYING OF TANNIN SOLUTION TO OBTAIN TANNIN IN POWDER FORM

Figure 1: Process flow sheet for extraction of tannin from the bark of Arjuna tree.

Thus, the quantity of bark chips processed per day = 9000/ (4*30) = 75 kg

Time per batch: Leaching time	2 hours
Setup time (loading and unloading)	1 hour
Total	3 hours

Assuming 9 hours of operation per day, 3 batches (of 25 kg bark in each batch) can be processed daily. This study optimized the process conditions so that the Arjuna bark could be commercially utilized for the extraction of tannin. Since the extraction process makes use of commonly used materials and equipment, it can be implemented in a small scale village industry. The method is highly cost effective, simple and can meet the needs of local tanneries.

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