APPLICATION OF AHP TOOL FOR DECISION MAKING OF CHOICE OF TECHNOLOGY FOR EXTRACTION OF ANTI-CANCER BIOACTIVE COMPOUNDS OF PLANT ORIGIN

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ABSTRACT

Demand for medicinal plants and their exploitation around the world has prompted international agencies like the World Health Organization (WHO) and national health departments like AYUSH to focus on their sustainable utilization. However, lack of any decision-making methodology makes it difficult for the rural entrepreneur to setup a business. This paper has developed a Multi-Criteria Decision Making template, using the Analytic Hierarchy Process (AHP), of ranking the best technology for extraction of nine medicinal plants which grow in Western Ghats of India. These plants have more than 20% subsidy in cultivation under NMMP and have an anticancer property. The technologies selected for AHP were agitation/centrifugation, cold solvent extraction, reflux/soxhlet extraction, cold percolation, microwave assisted extraction, sonication and hot solvent extraction. The ability of the tool to provide selection of the extraction technology with process flexibility like criteria selection, technology selection and criteria weightages allows its use by rural entrepreneurs, technology facilitators, rural entrepreneur proposal evaluators and policy makers.

Keywords: Extraction Technology Selection, Medicinal Plants, Analytic Hierarchy Process, Rural Entrepreneur

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1. Introduction

The demand for medicinal plants(MP) is increasing (Cragg & Newman, 2005; World Health Organization, 2000) due to their usage both as a source of active ingredients for modern medicine (Rajasekharan, 2006) as well as for producing herbal products while providing a viable business opportunity to entrepreneurs. Business opportunities in processing MP can help small scale collectors and cultivators get on the industrialization ladder and pursue their livelihood as an industrialist. While the large scale nutraceuticals/pharmaceuticals have the resources to carry out their own research towards technical know-how for industrial set-up, the real challenge exists for the small scale or rural entrepreneurs due to their limited resources and capacity. The small-scale or rural entrepreneurs' must mostly rely on knowledge in the public domain.

Public domain knowledge on natural products has focused mainly on developing/validating products (Choochote et al., 2004; Malik et al., 2007; Saxena et al., 2007) and developing/optimizing processing technology (Bothiraja, Joshi, Dama, & Pawar, 2011; Jyothi D Khanam S Sultana R, 2010). In the case of natural products, "processing technologies" depend upon the MP to be processed, and many times availability of MP for processing depends upon the suitability of the ecosystem /geographical area, current government policies and the market. Thus, the real challenge for the small scale/rural entrepreneur is choosing the technology which can process multiple MP so as to make their business viable. This creates a need for a multi-criteria decision making tool to select the best "processing technology" for their business.

India, with plans to capitalize on the global MP trade, launched the "National Mission on Medicinal Plants (NMMP)" in 2008.One of the goals was to promote processing by providing financial, technological and market support. However, India's efforts to enable the rural entrepreneur to process MP is inadequate as NMMP is 'technology silent', *i.e.* it does not provide any information about "processing technologies" that are compatible with different medicinal plants, or the decision-making process for selecting a "processing technology"(National Medicinal Plants Board, 2008).Thus, the need for a standardized decision-making process is felt at three different levels:

- At the rural entrepreneur level: The task of selecting the appropriate "processing technology" is challenging for the rural entrepreneur with limited resources and technical know-how.
- At the NMMP evaluator level: NMMP needs to evaluate the project proposals sent by the different entrepreneurs for financial support.
- At the NMMP board level: Better trade requires coordination between national and global systems which can be done through NMMP support to rural entrepreneurs in decision making as NMMP can provide much bigger picture to the rural entrepreneur with help of its resources.

There are several challenges from the rural entrepreneur's perspective in using the decision-making process to make their business viable with or without government support. Firstly, the amount of information which the entrepreneur needs to process is very high for different parameters like medicinal plants (2400 in Indian System of Medicine (ISM) (Ved & Goraya, 2008)), extraction technologies (more than 16 (Handa, Khanuja, Longo, & Rakesh, 2008; Xiang, Jianzhong, Jing, & Yundong, 2011)), bioactive compounds with medicinal property (thousands) and medicinal plant parts. Secondly, the time and resources which the entrepreneur may have to invest to acquire all this information could be a limiting factor especially with knowledge and resource constraints. Thus, processing this information in order to determine an appropriate "extraction technology/alternative" for each medicinal plant, plant part and bioactive compound can be done by the national level agencies. Once this has been done the rural entrepreneur can use the information to identify the best technology based on the medicinal plants of his/her choice. This study focuses on developing a simple decision-making template which can provide guidance to a rural entrepreneur for making decisions about an "extraction technology/alternative" to enable a viable business model. The Analytic Hierarchy Process (AHP),a simple and easy multi-criteria decision making tool, developed by the mathematician Thomas Saaty (Saaty, 1980), is used for selection of alternatives in the current study.

2. Methodology

The decision-making template is developed keeping in view the major decisions which the rural entrepreneur has to make while deciding upon the extraction technology/alternative for his/her business. First, the rural entrepreneur must decide upon the medicinal plants whose processing can be done with commercial viability based on the geographical area of the processing unit, source of medicinal plants, markets for the medicinal plant and government policies. Second, the entrepreneur must select the extraction technology/alternative for the business, which consists of two sub-tasks namely identification of extraction technologies/alternatives and rating of the extraction technologies/alternatives. These choices are converted into a decision-making template as shown in Figure 1.

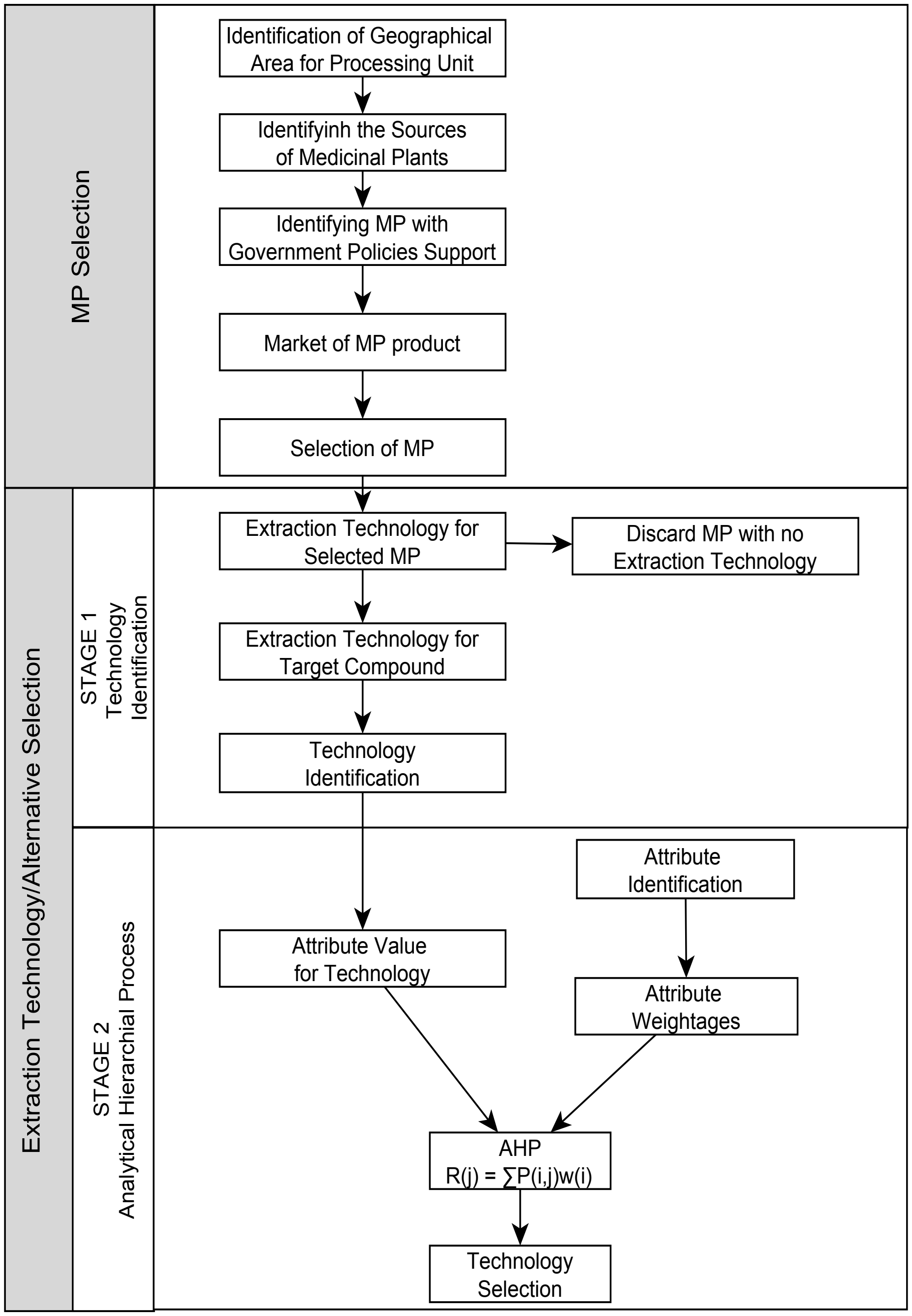

Figure 1 Methodology

2.1 Selection of medicinal plants

In the current study, the method of selecting medicinal plants has been a process of elimination based on geographical area of the processing unit, source of medicinal plants, market for the medicinal plant and government policies to select only those plants which satisfy all the criteria. The geographical area of processing and source of medicinal plants is the Western Ghats (WGs) of India, which is spread across 5 states (22 districts) (Kholkute, 2008) which covers around 6% of India's total land area, and contains 30% of Indian flora, fish, bird and mammal species making it one of the 34 global biodiversity hotspots identified for conservation (Critical Ecosystem Partnership Fund (CEPF), 2007). The source of medicinal plants and the geographical area of processing are kept the same as the entrepreneurs considered in this study are small scale cultivators who will be using the raw material cultivated on their farms. A survey by the Indian Council of Medical Research provided a shortlist of500 medicinal plants in WG with the capability to treat 200 diseases(Kholkute, 2008).A screening for government promotion and support to medicinal plants through NMMP (which is giving a subsidy from 20% to 75% on medicinal plant cultivation) resulted in 34 plants as shown in Table 1. Further screening using the market for medicinal plants is based on the medicinal property possessed by the plants. In the current study, an anti-cancer property is selected, because in the non-communicable disease category, cancer has been reported as the leading cause of death after cardiovascular disease (World Health Organization (WHO), 2008, 2011).

Ten medicinal plants namely *Alstonia scholaris* R.Br., *Coscinum fenestratum* (Gertn) Colebr., *Gloriosa superba* Linn., *Plumbago zeylanica* Linn., *Smilax china* Linn., *Terminalia arjuna* (Roxb.) Wt.&Arn., *Terminalia chebula* Retz., *Vitex nigundo* Linn., *Withania somnifera* (Linn.) DunaJ.and*Woodfordia fruticosa* Kurz. (shown in Table1 in bold and italics))were selected for this study. These plants satisfied the criteria of growing naturally in WG, getting more than 20% subsidy in NMMP and being scientifically verified for an anti-cancer property with a specific anti-cancer compound.

Table 1
Medicinal plants mentioned in NMMP list which grow in WGs, with those plants given > 20% subsidy and having an anticancer property (given in bold and italics)

WG plants mentioned in NMMP		
Acorus calamus Linn.	***Alstonia scholaris* R.Br.**	*Andrographis paniculata* (Burmi) Wall ex. Nees
Aloe vera (Linn.) Burn.	*Asparagus racemosus* Wild.	***Coscinum fenestratum* (Gertn) Colebr.**
Aegle marmelos (Linn) Corr.	*Azadirachta indica* A. Juss	*Cryptolepis buchanani* roem & schult
Embelia ribes Burm. f.	*Boerhaavia diffusa* Linn.	*Pterocarpus marsupium* Roxb.
Garcinia indica Choisy	*Centella asiatica* (Linn.) Urban	*Rauwolfia serpentina* Benth. ex Kurz
***Gloriosa superba* Linn.**	*Dioscorea bulbifera* Linn.	***Saraca asoca* (Roxb.) De Wilde***
Mesua ferrea Linn.	*Gymnema sylvestre* R. Br.	***Terminalia arjuna* (Roxb.) Wt. & Arn.**
Piper longum Linn.	*Hemidesmus indicus* R.Br.	***Terminalia bellirica* Gaertn.***
Santalum album Linn.	*Ocimum sanctum* Linn.	*Tylophora asthmatica* (Linn. f.) Wight & Am.
Smilax china Linn.*	***Plumbago zeylanica* Linn.**	***Withania somnifera* (Linn.) DunaJ.**
Solanum nigrum Linn.	***Terminalia chebula* Retz.**	
***Vitex nigundo* Linn.**	***Woodfordia fruticosa* Kurz.**	

(Note: Medicinal Plants in Bold and Italics gets more than 20% subsidy and have anti-cancer property, *: Literature have shown its anticancer property but no specific compound has been reported and hence not considered for this study, **: Lack of adequate literature to confirm the extraction technology)

2.2 Selection of extraction technology/alternative

Most of the techniques used in modern herbal processing make use of solvent extraction technology, which is based on the principle of distribution of one or more components between two immiscible or almost immiscible liquids. In some cases, the techniques make use of a single solvent and only compounds soluble in that solvent get extracted (Bharathi, Philomina, & Chakkaravarthi, 2006; Kannan et al., 2007). These technologies can be used either alone or in combination. For example, surfactant based extraction has been used along with microwave assisted extraction (MAE)(Chen, Yuchun, & Huizhou, 2007), sonication (He et al., 2005; Xiang et al., 2011), pressurized liquid extraction (PLE)(Choi, Chan, Leung, & Huie, 2003; Eng, Heng, & Ong, 2007) and agitation (He et al., 2005). Soxhlet extraction has been used along with microwave (García-Ayuso & Castro, 1999) as well as sonication (Luque-García & Castro, 2004).

Various extraction technologies under research or commercial use currently include agitation/centrifugation, cold solvent extraction, hot solvent extraction, cold percolation, reflux, PLE, super-critical fluid extraction (SCFE), sonication, MAE, steam distillation, hydro distillation, counter-current extraction (CCE), solid-phase extraction (SPE), enzymatic extraction, decoction (Handa, Khanuja, Longo, & Rakesh, 2008) and surfactant based extraction (Xiang, Jianzhong, Jing, & Yundong, 2011). They form the global set of extraction alternatives for this study. The entire extraction alternative selection process has two stages. Stage 1 is the selection of the relevant extraction technologies from the global set of extraction alternatives using preliminary criteria as discussed in this section. Stage 2 involves final selection of an extraction technology/alternative using AHP.

2.2.1 Stage 1: Identification of extraction alternatives for medicinal plants

In the current study, extraction alternatives with stand-alone use have been considered for analysis from the global set of extraction alternatives. This is based on the criteria that the alternatives used should have been reported for the extraction of an anti-cancer compound from at least one of the medicinal plants selected in Section 2.1. Vice versa, the medicinal plant needs to have been reported to have been used at least one of the technologies; otherwise as shown in Table 1, the MP is dropped from further study. Hence, in the current study, only nine MP and seven extraction technologies/alternatives are selected (see Table 2).

Table 2
Extraction technology with attributes

ET	**Raw Material Characteristics**			**Operating Characteristics**								**Managerial Characteristics**			
	Plant	**CC**	**PP**	**T**	**TBCP**	**P**	**S**	**T**	**IEF**	**AUE**	**SA**	**TA**	**M**	**S/T**	**TC**
Agitation (A1) [i]	C.f, G.s	IqA, PAa	Plant, Seed, Stem, Tuber	Low to V H	Tl, MTs, HTs, Ts,	1	P, NP	190 to 12500	Man,Elec	BC, C, pH	4 to 161	Easy	Easy	VB	Low

Cold Percolation (A2) [ii]	T.a, W.s, C.f	Triterpene, SL, IqA	Bark, Root, Stem	Low to Normal	Tl, MTs	1	P, NP	3400	No	BC, C, pH	167	Med	Easy	VB	Med
Cold Solvent (A3) [iii]	P.z, T.a, V.n, W.s, G.s, T.c, A.s, C.f,	Triterpene, PA, SL, IA, IqA, PAa, Lignan, Quinone	Bark, Leaf, Root, Seed, Stem, Tuber, Plant,	Low to Normal	Tl, MTs	1	P, NP	960 to 7200	No	BC, C, pH	2 to 54	VE	VE	VB	VL
MAE (A4) [iv]	W.s	SL	Aerial Part, Leaf	VH	HTs	1	P, NP	2 to 2.5	Elec	C, pH	17 to 20	Med	Tough	Med	High
Reflux (A5) [v]	P.z, G.s, V.n, A.s, W.s, C.f	Quinone, Lignan, SL, IA, IqA, PAa	Bark, Leaf, Plant, Root, Stem, Tuber	High to VH	Ts, HTs	1	P, NP	120 to 4300	Elec, Ther	No	1.5 to 200	Med	Med	Basic	Med
Sonication (A6) [vi]	A.s	IA	Bark	Low to VH	Tl, MTs, Ts, HTs	1	P, NP	540	Elec	BC, C, Ph	32	Tough	Tough	Med	VH
Hot Solvent (A7) [v]	T.a, W.f, C.f	Triterpene, PA, IqA	Leaf, Stem Stem	High to VH	Ts, HTs	1	P, NP	120	Elec, Ther	BC, C, pH	5.1	Easy	Med	Basic	Low

Note: [i]= (Bharathi et al., 2006; Chomnawang, Trinapakul, & Gritsanapan, 2009; Kannan et al., 2007; Kavina, Gopi, & Panneerselvam, 2011; Rojsanga & Gritsanapan, 2005; Rojsanga, Gritsanapan, & Suntornsuk, 2006; Tungpradit, Sinchaikul, Phutrakul, Wongkham, & Chen, 2011),
[ii]= (Malik et al., 2007; Rojsanga et al., 2006; Upadhyay, Pandey, Jha, Singh, & Pandey, 2001),
[iii]= (Bothiraja, Joshi, Dama, & Pawar, 2011; Chitra, Sujatha, Polisetti, Karri, & Reddy, 2011; Choochote et al., 2004; Dalavayi, Kulkarni, Itikala, & Itikala, 2006; Jayaprakasam & Nair, 2003; Lin et al., 1990; Macabeo et al., 2005; Malhotra, Taneja, & Dhar, 1989; Malik et al., 2007; R. K. Pawar, Shivani, Singh, & Sharma, 2010; R. S. Pawar & Bhutani, 2005; Pinho et al., 1992; Saxena et al., 2007; D. V. Singh, Verma, Singh, & Gupta, 2002; Unnikrishnan, Raja, & Balachandran, 2008; Yibchok-anun, Jittaprasatsin, Somtir, Bunlunara, & Adisakwattana, 2009; Zhou et al., 2009),
[iv]= (Jyothi D Khanam S Sultana R, 2010; Jyothi, Khanam, & Sultana, 2010; Mirzajani, Ghassempour, Jalali-Heravi, & Mirjalili, 2010),
[v]= (Bharathi et al., 2006; Britto & Sujin, 2012; Deevanhxay et al., 2009; Devi, Utsumi, Takata, & Takeda, 2008; Jagetia & Baliga, 2005; Jeyachandran, Mahesh, Cindrella, Sudhakar, & Pazhanichamy, 2009; Jyothi D Khanam S Sultana R, 2010; Jyothi et al., 2010; Rojsanga et al., 2006; Tran et al., 2003; Venukumar, 2004; Zhou et al., 2005),
[vi]= (Lee et al., 2012),
[vii]= (Kadota et al., 1990; Moulisha, Kumar, & Kanti, 2010; Stenhouse, 1867),

A.s= *Alstonia scholaris* R.Br.	AUE= Ability to use Enhancers	BC= Biochemical	C.f= *Coscinum fenestratum* (Gertn) Colebr.
C= Chemical	CC=Compound Class	Elec= Electrical	ET=Extraction Technology
G.s= *Gloriosa superba* Linn.	HTs= Hyper Thermostable	IA= Indole Alkaloid	IEF=Input Energy Form

IqA= Isoquinoline Alkaloid	M= Maintenance	Man= Manual	MTs= Mild Thermostable
NP= Non Polar	P.z= *Plumbago zeylanica* Linn.	P= Polar	P= Pressure Applied (atm)
PA = Phenolic Acid	PAa= Phenyl Alkylamines	PP= Plant Part	S/T= Skills/Training
S= Solvents	SA= Solvent Amount (ml/gm of solid sample)	SL= Steriodal Lactone	T.a= *Terminalia arjuna* (Roxb.) Wt. & Arn.
T.c= *Terminalia chebula* Retz.	T= Temperature in °C	t= Time in minutes	TA= Technology Availability
TBCP=Temperature Based Compound Property	TC=Technology Cost	Ther= Thermal	Tl= Thermolabile
Ts= Thermostable	V.n= *Vitex nigundo* Linn.	VB= Very Basic	VE= Very Easy
VH= Very High	VL= Very Low	W.f= *Woodfordia fruticosa* Kurz.	W.s= *Withania somnifera* (Linn.) DunaJ.

2.2.2 Stage 2: Analytical Hierarchy Process (AHP)

AHP has the following three steps as shown in Stage 2 of Figure 1:

- Performing pair-wise comparisons of the criteria and providing weightages forthe criteria for concerned perspective.
- Prioritization of technologies/alternatives is given for each of the criteria selected.
- Finally, summation of the product of the criteria and technology/alternative weightages to arrive at best alternative.

AHP allows the user to use both the quantitative and qualitative data with consideration for even the subjective aspect of the decision like intuition and personal experiences (Montevechi et al., 2010; Palcic & Lalic, 2009). It has beenused for selection of alternatives for various purposes like:

- brand selection (Ultrasonic Scanning Machine (Montevechi, Guimaraes, Oliveira, & Friend, 2010), neonatal ventilators (Sloane, Liberatore, Nydick, Luo, & Chung, 2003)),
- site selection and allocation (landfill site (Hasan, Tetsuo, & Islam, 2009; Javaheri, Nasrabadi, Jafarian, Rowshan, & Khoshnam, 2006; Yahaya, Ilori, Whanda, & Edicha, 2010), sustainable coastal tourism (Abed, Monavari, Karbasi, Farshchi, & Abedi, 2011), railway station (Mohajeri & Amin, 2010)),
- technology selection (waste water treatment for electroplating industry (Dabaghian, Hashemi, Ebadi, & Maknoon, 2008), solar thermal collection technology (Nixon, Dey, & Davies, 2010), municipal solid waste management (Thampi & Rao, 2012)),
- policy making (solar energy technologies utilization (Elkarmi & Mustafa, 1993), energy conservation utilization (Kablan, 2004)),
- production planning (integrated production planning considering manufacturing partners (Jung, 2011), total productive maintenance justification (Kodali & Chandra, 2001), push, pull and hybrid push-pull systems classification (Razmi, Rahnejat, & Khan, 2005)), and

- treatment alternatives (upper limbs treatment for persons with tetraplegia (Hummel, Snoek, van Til, van Rossum, & Ijzermann, 2005), pharyngitis management in adults (S. Singh, Dolan, & Centor, 2006)).

A Java-based in-house AHP software developed at IIT-Bombay which allows the user to provide qualitative and quantitative criteria for analysis has been used for this study (Mahajan, Ramakrishnan, & Date, 2008).The criteria can be benefit or cost based depending on the user's perspective and accordingly, the benefits criteria value should be maximized and the costs criteria value should be minimized (Nijkamp & Delft, 1977). The qualitative criteria analysis has been done by performing pair-wise comparisons of alternatives, and giving priority based on higher benefits or minimum costs. This analysis solves the problem of benefit-cost integration. Quantitative criteria have been classified as benefits and costs, and the benefit-cost integration problem has been solved by the in-house AHP software by converting cost into benefit[1].

2.2.2.1 Identification of criteria for selection

The selected extraction alternatives need to be compared using common criteria (good mix of qualitative and quantitative) to predict an appropriate alternative. The commercial application of an extraction technology needs to consider three main decision criterion characteristics: raw material characteristics (RMC), technical characteristics (TC) and managerial/feasibility characteristics (MC). Each of these decision criterion characteristics have criteria, a total of 14 have been identified (Table 3). The rural entrepreneurs' need to evaluate alternatives using those 14 criteria requires a strategy which is simple enough for them to understand, however this kind of strategy may be too laborious and time consuming. This leads to the use of two different strategies for this study namely single level hierarchy (Figure 2) and two level hierarchy (Figure 3). Single level hierarchy is a simple strategy, which could be easily understood by the rural entrepreneur with knowledge constraints, as all the 14 criteria are taken simultaneously. Two level hierarchy is less laborious and time consuming, and can be used by people with a better understanding of the logic. Two level hierarchy uses three criterion characteristics at the first level followed by segregation of the 14 criteria under them. The comparison of the results of these two strategies can help determine the relative change in the ranking of the most appropriate alternative as well as provide the user the option of using a strategy as per his/her competence.

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[1]The Java tool normalization scheme developed in (Raju, Rangaraj, & Date, 1995) for conversion of cost to benefit using following normalized equations:

Benefit criteria:

$$p_{ij} = \frac{t_{ij}-t_i^{min}}{t_i^{max}-t_i^{min}} \qquad (1)$$

Cost criteria:

$$p_{ij} = \frac{t_i^{max}-t_{ij}}{t_i^{max}-t_i^{min}} \qquad (2)$$

Where, $t_{ij}$is the attribute value of the *j*th alternative with respect to the *i*th attribute and t_i^{max} and t_i^{min} are the absolute maximum and minimum values among all the alternatives for the *i*th attribute. These equations have been directly taken from.

Table 3
List of criterion characteristics and criteria selected for AHP with single or two-level hierarchy

Criterion Characteristics	Crit-erion	Name	Description	Criterion Type	Cost/ Benefit
Raw Material Characteristics (RMC)	C1	Number of Plants	It is the raw material characteristic of the technology which determines the number of plants among the selected for which the technology has been used.	Quantitative	Benefit
	C2	Number of Compound Classes	It is the raw material characteristic of the technology which determines the number of compound classes among the selected classes for which the technology has been used.	Quantitative	Benefit
	C3	Number of Plant parts	It is the raw material characteristic of the technology which determines the number of different types of plant parts of the selected medicinal plants for which the technology has been used.	Quantitative	Benefit
Technical Characteristics (TC)	C4	Temperature Range	It is the operating characteristic which determines the temperature range and the temperature specific compounds which can be extracted in that range for the extraction technology.	Qualitative	Benefit
	C5	Pressure Application (atm)	It is operating characteristics which determine the pressure which need to be applied for the working of the extraction technology.	Quantitative	Cost
	C6	Type of Solvents	It is the operating characteristics which determines the number of different solvents which can be used by the extraction technology	Quantitative	Benefit
	C7	Minimum Time (min)	It is the operating characteristic which determines the minimum time taken by the extraction technology for the selected plants and compound class.	Quantitative	Cost
	C8	Input Energy Form	It is the operating characteristic which determines the different forms of external energy used by the extraction technology.	Qualitative	Benefit
	C9	Use of Enhancers	It is the operating characteristic which determines the number of different types of enhancers which can be used by the extraction technology.	Quantitative	Benefit
	C10	Minimum Solvent (ml/gm)	It is the operating characteristic which determines the minimum solvent taken by the extraction technology for the selected plants and compound class.	Quantitative	Cost
Managerial Characteristics (MC)	C11	Technology Availability	It is the ease with which the technology or makeshift technology which can be acquired.	Qualitative	Benefit
	C12	Maintenance	It is the ease of maintenance of extraction technology which includes financial and non-financial costs and benefits.	Qualitative	Benefit
	C13	Skills/ Training	It is the skill/training required in order to use the extraction technology.	Qualitative	Cost
	C14	Technology Cost	It is cost of the technology instrument.	Qualitative	Cost

Common raw material characteristics mentioned by various researchers are medicinal plant species, target compound class and medicinal plant part as shown in Table 2. In this study, these raw material characteristics have been used for designing three criteria: number of plants (C1), number compound classes (C2) and number of medicinal plant parts (C3). Some of the criteria important for the extraction of phyto-chemicals include plant material, extraction time, pH, temperature, solvent to solid ratio, extraction procedure and extraction solvent as discussed by Tiwari, Kumar, Kaur, Kaur and Kaur (2011). Many research papers also talk about the use of certain enhancers like chemicals, bio-chemicals and pH with certain extraction technologies to produce better results (Table 2). Another technical characteristic which can be implicitly identified from research papers is the energy (such as manual, electrical or thermal) used to run the extraction technology. These parameters, which reflect the adaptability of the extraction technology, have been used in the current study and criteria have been developed for technical characteristics. The technical characteristics criteria used are temperature range (C4), pressure application (C5), type of solvents (C6), minimum time (C7), input energy form (C8), use of enhancers (C9) and minimum solvent (C10). Managerial characteristics, which influence the technology choice, are technology availability (C11), maintenance (C12), skills/training (C13) and technology cost (C14).

Quantitative criteria can be beneficial or detrimental depending on the perspective of the rural entrepreneur. An increase in the benefit score increases the score of the technology, while an increase in the cost score decreases the score of the technology. Raw material characteristics based criteria (C1-C3) are quantitative criteria providing benefits to the technology user. Criteria based on technology operating parameters (C4-C10) are a mix of quantitative and qualitative criteria. The quantitative criteria, pressure (C5), time (C7) and solvent amount (C10) are crucial as they indirectly affect the cost of the technology while solvent type (C6) and enhancers (C9) determine the robustness. Temperature range (C4) and input energy form (C8) are qualitative criteria which contribute to the robustness and cost of the technology. Management characteristics based criteria (C11-C14) are qualitative in nature due to lack of quantitative data. They determine the accessibility of the technology (C11) and cost of the technology as maintenance (C12), labor skills (C13) and initial investment (C14).

In the given set of criteria, the aspects of environment and employment are not included, since the existing selection decisions of a rural entrepreneur usually are not focused on the impact on the environment and employment generation. Also, certain operating parameters like energy form, pressure applied, operating time and solvent amount can indirectly indicate the relative environmental impact of the technologies.

2.2.2.2 Criteria weightages

The perspective of the rural entrepreneur determines relative criterion scores. As per the perspective adopted for the AHP process, pair-wise comparison amongst the criteria is performed by giving the relative weightage on the numerical scale of 1 to 9 to obtain the global/local weightages of the criteria for the single level hierarchy (SLH) (Figure 2)given in Table 4 .In the case of two level hierarchy (Figure 3), the criteria local weights were determined by performing the pairwise comparison for criteria C1-C3, C4-C10 and C11-C14 (as shown in dark bordered boxes in Table 4). Further, the criteria local weights in Table 4 were used to determine the global weights for criteria in two-level hierarchy as shown in Table 5. In the present case, criterion characteristics and criteria weightages were determined during a project to identify rural livelihood potential. This activity tried to imitate the rural entrepreneur's access to information and expertise, and hence has been based on informal interactions. The rural people identified for interactions were four small business holders and farmers with knowledge of medicinal plants and an acumen/potential interest for a medicinal plant based business. The local expertise on running a business and identifying plants for agriculture was used for developing preferences. The weightages to these preferences was given by the researchers based on their personnel experiences; as a result the problem of aggregation of the individual judgments did not arise. The consistency index for single and two level AHP are lower because the weightages were calculated in reference to a single user (rural entrepreneur).

In the case of the rural entrepreneur initiative, the commercial interest is assumed to govern the technology selection making managerial characteristics (MC) (C11-C14) the highest priority. These characteristics determine ease of managing a business. Cost of technology (C14) is most important as it affects the initial investment. Technology availability (C11) is very important as information and supplier accessibility can be a problem in rural areas due to lack of industrialization. Skills (C13) are important due to investment of time and money required if skill development/procurement needs to be performed. Maintenance (C12) is important as it affects operating cost and breakdown time of the technology.

Raw material characteristics (RMC) are given higher priority than technological characteristics (TC) since they determine the vagaries for the success of the rural entrepreneur initiative rather than the technological characteristics which have already been scientifically validated. Raw material characteristics decide the use of the technology for the desired medicinal plants (C1). They are very important from the rural entrepreneur's perspective as an opportunity provided by the diverse medicinal plants availability in a region can be used only with technology which can use those plants. Similarly, diverse compound class (C2) and plant parts (C3) utilization ability of technology provides the opportunity to produce multiple products and use multiple plant parts from same plant.

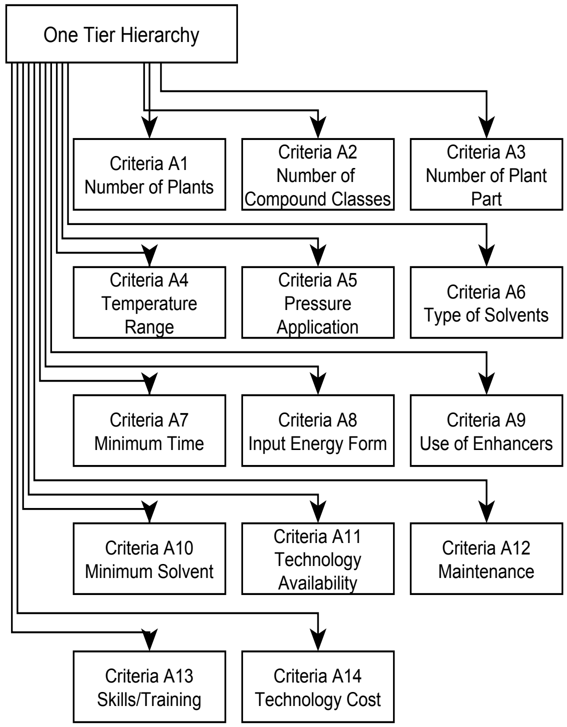

Figure 2 Single-level hierarchy

Table 4
Pairwise comparison of criteria (C1-C14) for single-level hierarchy (SLH)(additional usage of pairwise comparison of criteria in black boxes i.e., C1-C3, C4-C10 and C11-C14 used for obtaining local weights for two-level hierarchy (TLH)).

Perspective=Rural Entrepreneur																
Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**SLH Wt. (Local/Global**	**TLH Wt. (Local)**
C1	1.0	0.9	1.0	2.0	3.0	6.0	1.2	1.5	6.0	1.0	0.8	1.0	0.9	0.7	0.08	0.321
C2	1.2	1.0	1.2	2.3	3.5	7.0	1.4	1.8	7.0	1.2	0.9	1.2	1.0	0.8	0.10	0.366
C3	1.0	0.9	1.0	2.0	3.0	6.0	1.2	1.5	6.0	1.0	0.8	1.0	0.9	0.7	0.08	0.313
C4	0.5	0.4	0.5	1.0	1.5	3.0	0.6	0.8	3.0	0.5	0.4	0.5	0.4	0.3	0.04	0.139
C5	0.3	0.3	0.3	0.7	1.0	2.0	0.4	0.5	2.0	0.3	0.3	0.3	0.3	0.2	0.03	0.091
C6	0.2	0.1	0.2	0.3	0.5	1.0	0.2	0.3	1.0	0.2	0.1	0.2	0.1	0.1	0.01	0.049
C7	0.8	0.7	0.8	1.7	2.5	5.0	1.0	1.3	5.0	0.8	0.6	0.8	0.7	0.6	0.07	0.229
C8	0.7	0.6	0.7	1.3	2.0	4.0	0.8	1.0	4.0	0.7	0.5	0.7	0.6	0.4	0.06	0.179
C9	0.2	0.1	0.2	0.3	0.5	1.0	0.2	0.3	1.0	0.2	0.1	0.2	0.1	0.1	0.01	0.047
C10	1.0	0.9	1.0	2.0	3.0	5.9	1.2	1.5	5.9	1.0	0.8	1.0	0.9	0.7	0.08	0.266
C11	1.3	1.1	1.3	2.7	4.0	8.0	1.6	2.0	8.0	1.3	1.0	1.3	1.1	0.9	0.11	0.264
C12	1.0	0.9	1.0	2.0	3.0	6.0	1.2	1.5	6.0	1.0	0.8	1.0	0.9	0.7	0.08	0.207
C13	1.2	1.0	1.2	2.3	3.5	7.0	1.4	1.8	7.0	1.2	0.9	1.2	1.0	0.8	0.10	0.235
C14	1.5	1.3	1.5	3.0	4.5	9.0	1.8	2.3	9.0	1.5	1.1	1.5	1.3	1.0	0.13	0.294
															C.I.=5.081E-6	

In the case of technology criteria, higher priority is given to the cost related criteria (C4, C5, C7, C8 and C10) as compared to the benefit criteria as these affect the cost of the technology, operating cost and additional investment which need to be made for using that technology. Among the cost related criteria, criteria (C7-C10) are given higher priority. Solvent amount (C10) plays a critical role as it affects both the operating cost, handling and environmental and water impact of technology on the area. Time (C7) will affect the operating cost, net working capital and process cycle as longer time means higher risk. Energy form (C8) will affect operating cost and initial investment.

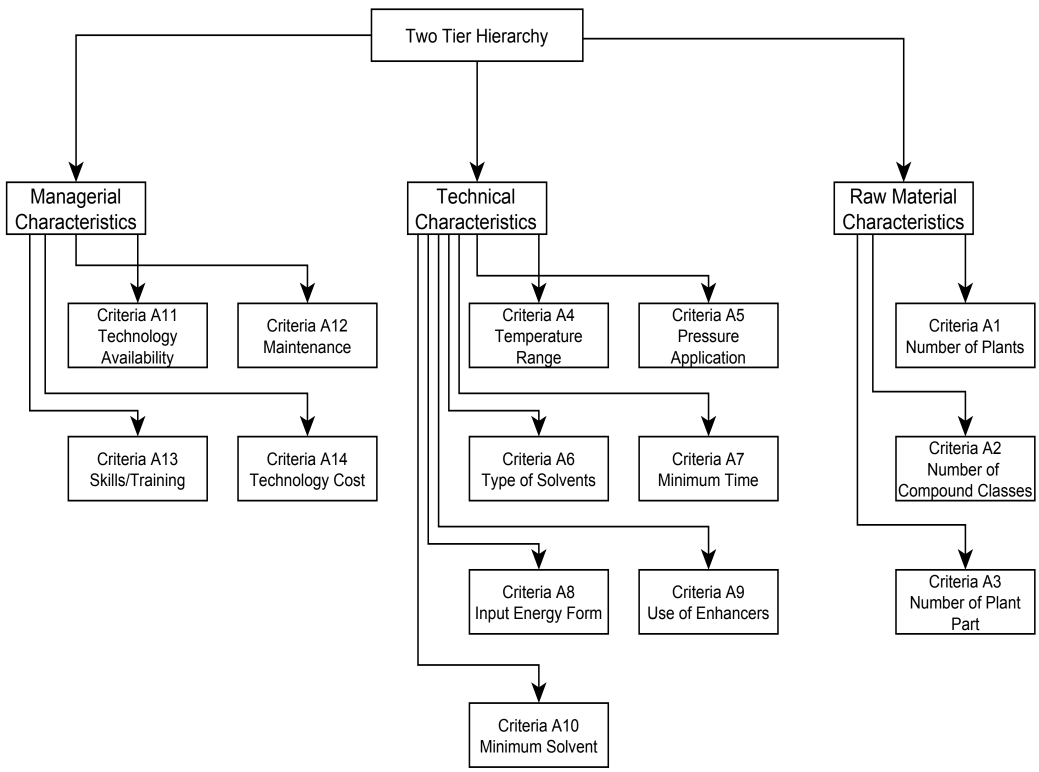

Figure 3 Two-level hierarchy

Table 5
Pair-wise final normalized criterion characteristics and criteria weightages for two-level hierarchy

Criterion Characteristics	Local Weight	CI	Criteria	Local Weight	CI	Global Weight
RMC	0.297	8.9E-03	C1	0.321	6.3E-04	0.095
			C2	0.366		0.109
			C3	0.313		0.093
TC	0.163		C4	0.139	1.4E-03	0.023
			C5	0.091		0.015
			C6	0.049		0.008
			C7	0.229		0.037
			C8	0.179		0.029
			C9	0.047		0.008
			C10	0.266		0.044
MC	0.540		C11	0.264	1.2E-04	0.142
			C12	0.207		0.112
			C13	0.235		0.127
			C14	0.294		0.159

2.2.2.3 Criteria scores for technology

The quantitative score for the criteria as shown in Table 6 has been selected through a detailed literature survey as indicated in Table 2. In the case of the benefit related criteria, number of plants (C1), number of compound classes (C2) and number of plant parts (C3) numbers are allocated based on the amount found for each criterion in the literature. For example, Reflux technology (A5) was used for six medicinal plants namely *Plumbago zeylanica*Linn.,*Vitex nigundo* Linn., *Withania somnifera* (Linn.) DunaJ.,*Alstonia scholaris* R.Br., *Coscinum fenestratum* (Gertn) Colebr. and*Gloriosa superba* Linn. among the eight desired medicinal plants, so the number of plants (C1) criterion score for Reflux technology (A5) is six. Criterion solvent type (C6) and use of enhancers (C9) scores were calculated based on the number of solvent type (polar and non-polar) and the number of enhancers (Chemical, Biochemical and pH) respectively which could be used with technology based on its extraction procedure. For example, in the case of reflux (A5), addition of surfactants or enzymes causing a change in solvent pH will not have an effect on extraction as the solvent is first evaporated and during condensation gets mixed with the sample. In the case of microwave assisted extraction very high temperatures can denature enzymes.

In the case of cost related criteria, pressure (C5), time (C7) and solvent amount (C10), different researchers have used different operating conditions for the technology of choice in their research. For the current study, to estimate the minimum achievable cost, the minimum score for the technology is taken. For example, for Reflux technology (A5) different researchers have reported different scores for time (C7) criterion ranging from 120 to 4320 minutes (Bharathi et al., 2006; Britto & Sujin, 2012; Deevanhxay et al., 2009; Jeyachandran et al., 2009; Jyothi D Khanam S Sultana R, 2010; Jyothi et al., 2010; Rojsanga et al., 2006; Tran et al., 2003; Zhou et al., 2005) for extraction. For this study, to arrive at a minimum achievable cost, the lowest score is selected. The time (C7) criterion for hot solvent extraction (A7) is not available in the literature for the desired medicinal plants. Reflux (A5) and hot solvent extraction (A7) work on a similar principle of extracting compounds from a sample in the presence of heat through solid phase extraction with the only difference being the reuse of the solvent in case of reflux (A5). As a result of this similarity, the time (C7) score of reflux (A5) is used as a proxy for hot solvent extraction (A7).

The qualitative score for the criteria as shown in Table 6 is selected based on the extraction procedure and intuition. The temperature range (C4) criteria are based on the operating temperature range of the technology and the temperature based compounds (Thermo labile, Mild Thermostable, Thermostable and Hyper-thermostable) which can be extracted. A technology with maximum operating range and potential to extract compounds can provide high adaptability and is given the highest score. External energy input (Manual, Electrical and Thermal) can add to the cost of the technology due to unavailability of a consistent source or high energy cost. Manual and thermal energy are preferred in rural areas as electricity supply in Indian villages is erratic. Firewood and solar power can be used as sources of thermal power. The use of more than one source of energy can increase the adaptability of the technology. Technology availability (C11) is determined based on the ease of its accessibility or ability to be made in local areas. Maintenance (C12) and Skills (C13) are determined based on the complexity of technology instruments and the extraction procedure. Cost of technology (C14) is determined based both on the possibility of local availability of the resource, complexity of technology and operating procedure.

Table 6
List of criteria selected for AHP

Criterion	Technology						
	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
C1	2	3	8	1	6	1	3
C2	2	3	8	1	6	1	3
C3	4	3	7	2	6	1	2
C4	Low to Very High	Low to Normal	Low to Normal	Very High	High to Very High	Low to Very High	High to Very High
C5	1	1	1	1	1	1	1
C6	2	2	2	2	2	2	2
C7	190	3393.33	960	2	120	540	120
C8	Manual or Electrical	No	No	Electrical	Electrical and Thermal	Electrical	Electrical and Thermal
C9	3	3	3	2	0	3	3
C10	4	167	2	17	1.5	31.6	5.15
C11	Easy	Medium	Very Easy	Medium	Medium	Tough	Easy
C12	Easy	Easy	Very Easy	Tough	Medium	Tough	Medium
C13	Very Basic	Very Basic	Very Basic	Medium	Basic	Medium	Basic
C14	Low	Medium	Very Low	High	Medium	Very High	Low

2.2.2.4 Technology ranking

The technology ranking was obtained by the summation of the product of the criteria and technology weightages for the different alternatives as shown in Equation 1 below.

$$R_i = \sum_{i=1}^{11} P(i,j)w(i) \quad (1)$$

Here, R_j = Ranking of the alternatives, P_{ij} = Normalized criteria score of the alternatives and w_i = Criteria weight. An overall ranking of the alternatives based on the total weighted score of the alternatives for the given criteria is created.

2.2.2.5 Sensitivity analysis

A sensitivity analysis of the tool is performed to determine the robustness of the results and to better understand the reason of the rankings of the alternatives. This allows the estimation of the impact of the individual criteria on the ranking. In this study, this is done by selective elimination of the score of single criterion from the AHP result as it can identify the criteria which played the main role in ranks by understanding the shifts in ranks. The criticality of the criterion depends on both the score distribution of the alternatives for that criterion and criterion weightage. The analysis can help in identifying the distribution of the score alternative which is required in order to maintain or change the ranking along with the maximum shift in ranking which can be expected. In this analysis, ranking of the technology was analyzed by removing a criterion, which is added back while removing any other criterion. For example, when criterion C1 is removed from the criteria set for AHP, it was added back in the criteria set of AHP when criterion C2 was removed. Criteria C5 and C6 were not considered for the sensitivity analysis because in the current study scores of criteria C5 and C6 have remained constant for all the technologies.

3. Results

In the case of the single hierarchy based alternative ranking (Table 7), the results show that the cold solvent extraction technology (A3) is the best technology for a rural entrepreneur. This is because the cost associated with this technology is lower as compared to other technologies as a result of the very low investment needed for the skills and technology required. The simplicity of the instruments needed make the technology and the maintenance very easy. This makes the validation of its use for all plants, compound classes and plant parts easy and cheap, which is indicated by the high score in the criteria C1, C2 and C3. The flexibility in the technological parameters, like ability to operate at different temperatures and extract different types of thermo-dependent compounds, no energy use, ability to use different enhancers with very low solvent requirements, provides a technical advantage to the extraction technology over others, which helps to compensate for the significant amount of time required by this technology. A sensitivity analysis of the technology (Table 8) with removal of different criteria from the AHP process one at a time did not affect the technology which indicates its robustness and equitable distribution of the characteristics of the technology over the criteria.

Table 7
Final criterion weights and Normalized criteria matrix for single level hierarchy

Criteria		Agitation	Cold Percolation	Cold Solvent Extraction	MAE	Reflux	Sonication	Hot Solvent Extraction
Name	**Weightage**	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
C1	0.08	0.140	0.286	1.000	0.000	0.710	0.000	0.286
C2	0.10	0.140	0.286	1.000	0.000	0.710	0.000	0.286
C3	0.08	0.500	0.333	1.000	0.170	0.830	0.000	0.167
C4	0.04	0.230	0.179	0.180	0.030	0.080	0.231	0.077
C5	0.03	1.000	1.000	1.000	1.000	1.000	1.000	1.000
C6	0.01	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C7	0.07	0.940	0.000	0.720	1.000	0.970	0.841	0.965
C8	0.06	0.130	0.300	0.300	0.100	0.030	0.100	0.030
C9	0.01	1.000	1.000	1.000	0.670	0.000	1.000	1.000
C10	0.08	0.980	0.000	1.000	0.910	1.000	0.818	0.978
C11	0.11	0.170	0.122	0.220	0.120	0.120	0.073	0.171
C12	0.08	0.180	0.180	0.230	0.080	0.130	0.077	0.128
C13	0.10	0.180	0.177	0.180	0.100	0.140	0.098	0.137
C14	0.13	0.190	0.135	0.240	0.080	0.130	0.027	0.190
Total Score		**0.353**	**0.211**	**0.562**	**0.245**	**0.442**	**0.214**	**0.332**
Final Rank		**3**	**7**	**1**	**5**	**2**	**6**	**4**

Reflux (A5) is the second best technology. It is a medium cost technology with availability of technology in nearby urban areas, medium level investment in terms of technology cost and maintenance and basic level skills requirement. A5 has fewer managerial characteristics as compared to technologies like agitation (A1), cold percolation (A7) and hot solvent extraction (A4), but the much better raw material characteristics offsets this disadvantage. The two most important technological characteristics C10 and C7 are the strengths of reflux which allows it to compensate for the low score in the other technological criteria. Very low weightage of the technological characteristics make this technology robust in the sensitivity analysis (Table 8).

The two lowest technologies, i.e., sonication (A6) and cold percolation (A2) were at the bottom mainly because of poor raw material characteristics. In the case of sonication, the managerial characteristics are weak because it has high technology and maintenance costs, and it is not easily available. Despite the lowest score in the most important characteristics, it was ranked higher than cold percolation because of the very strong major technological characteristics C4, C7, C10 as compared to cold percolation. It slipped to last in the rankings when either C7 or C10 were not considered (Table 8).

The sensitivity analysis (Table 8) indicated changes in the technology ranking with criteria elimination, but only in 3 out of 12 criteria. Changes in the technology rankings were observed in all technologies except cold solvent and reflux. Criteria C7 and C10 were the main criteria whose elimination showed changes in cold percolation, MAE and sonication. Secondly, these two attributes showed maximum shift in the rank of the technologies, with cold percolation rank shifting from 7 to 5 and demoting the rank of the microwave and sonication by one level with 4 shifts in rank observed overall. This is because cold percolation is very weak in these two criteria. In the case of agitation (A1) and hot solvent extraction (A7), the hot solvent score is only 5.9% less than the agitation score. As a result, there is rank reversal in the absence of the criterion C3.The change in ranking of certain technologies with elimination of certain characteristics indicates that the process can be modified as per the needs of the user. The user can alter the criteria list, criterion weightages, technologies and criterion scores. This tool can be used to select the whole processing strategy by performing the AHP of the different processing steps.

Table 8
Result of sensitivity analysis with selective removal of criteria for single level hierarchy

Criterion		**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**# of Technology Rank Changed**	**# of shifts in rank**
Default	Score	0.353	0.211	0.562	0.245	0.442	0.214	0.332	0	0
	Rank	3	7	1	5	2	6	4		
No C1	Score	0.341	0.187	0.477	0.245	0.382	0.214	0.308	0	0
	Rank	3	7	1	5	2	6	4		
No C2	Score	0.339	0.183	0.463	0.245	0.372	0.214	0.304	0	0
	Rank	3	7	1	5	2	6	4		
No C3	Score	0.311	0.183	0.477	0.231	0.372	0.214	0.318	2	2
	Rank	4	7	1	5	2	6	3		
No C4	Score	0.344	0.203	0.554	0.244	0.439	0.204	0.329	3	4
	Rank	3	7	1	5	2	6	4		
No C7	Score	0.287	0.211	0.511	0.175	0.374	0.155	0.264	0	0
	Rank	3	5	1	6	2	7	4		
No C8	Score	0.346	0.194	0.545	0.240	0.440	0.208	0.330	0	0
	Rank	3	7	1	5	2	6	4		
No C9	Score	0.339	0.197	0.547	0.236	0.442	0.200	0.318	3	4
	Rank	3	7	1	5	2	6	4		
No C10	Score	0.270	0.211	0.478	0.169	0.358	0.145	0.250	0	0
	Rank	3	5	1	6	2	7	4		
No C11	Score	0.334	0.197	0.537	0.232	0.428	0.206	0.313	0	0
	Rank	3	7	1	5	2	6	4		
No C12	Score	0.338	0.196	0.542	0.239	0.431	0.207	0.321	0	0
	Rank	3	7	1	5	2	6	4		
No C13	Score	0.336	0.193	0.544	0.236	0.429	0.204	0.318	0	0
	Rank	3	7	1	5	2	6	4		
No C14	Score	0.329	0.194	0.531	0.235	0.425	0.210	0.308	0	0
	Rank	3	7	1	5	2	6	4		

The change in hierarchy structure from single hierarchy to two-level hierarchy has not resulted in any major changes in the technology ranking (Table 9), with the only change observed in the lowest technologies A2, A6 and A7. This indicates that a change in hierarchy may not result in very strong changes in the current scenario. This means that whether the user tries single hierarchy or multiple hierarchy criteria for AHP, there will not be much impact on the top raking technologies.

Table 9
Result of technology decision changes with shift from single-level hierarchy to two-level hierarchy

Criterion		A1	A2	A3	A4	A5	A6	A7
Default	Score	0.353	0.211	0.562	0.245	0.442	0.210	0.332
	Rank	3	7	1	5	2	6	4
Two-level Hierarchy	Score	0.285	0.206	0.521	0.165	0.391	0.132	0.264
	Rank	3	5	1	6	2	7	4

4. Conclusion

A Multi-Criteria Decision Making tool (using AHP) of ranking the best technology for extraction of nine of the medicinal plants which grow in Western Ghats of India and have more than 20% subsidy in cultivation under NMMP and have an anticancer property was developed keeping the perspective of a "Rural Entrepreneur". The tool can be used by rural entrepreneurs using the developed simple strategy to select technologies as well as by the evaluators of the NMMP to evaluate the proposals from rural entrepreneurs for the successful set up of a medicinal plant processing unit. A Java-based software is used to perform AHP for the ranking of the technology for extraction from desired medicinal plants. This process keeps in view the interest and situation of rural entrepreneurs like geographical location, local availability of medicinal plants and other raw materials and product demand in the market. The study successfully selected cold solvent extraction technology which could be most easily and reliably used by the rural entrepreneur in a highly constrained local environment. Though, with the addition of more criteria, availability of more research information and technologies, the ranking of technologies could change. The attempt to showcase the utility of such a multi-criteria decision making tool using AHP in making decisions regarding the selection of the extraction technology still applies.

The flexibility of the tool lies in the ease of modification as per user needs by selecting the criteria the user wants to consider, allocating weightages to the criteria based on their perspective, inserting alternative criterion scores and modifying the criteria. The strategy of creating the two stage process facilitates the selection of technologies for the user in a simple and easy way. This tool can also be useful for the facilitation agencies to disseminate the appropriate technology for the desired medicinal plants, medicinal plant parts and compound class to the rural entrepreneurs. Policy makers and "rural entrepreneur proposal" evaluators can use this tool to provide differentiation in the processing subsidy for medicinal plants. For example, the maximum subsidy can be provided to the process and technology which ranks highest in the results. This will provide a more customized and flexible framework for the rural entrepreneur to work within. Rural entrepreneur proposal evaluators can also use this tool to validate the project proposals of rural entrepreneurs and map demand for different types of technologies for the geographical areas based on the results of the AHP.

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